BRENT WILEY, *Editor*

T. J. ESS, *Associate Editor*

JAMES D. KELLY, *Advertising Manager*

BOARD OF DIRECTORS

PRESIDENT
WILLIAM A. PERRY
Superintendent Electrical and Power Departments
Inland Steel Company
Indiana Harbor, Indiana

1ST VICE-PRESIDENT, THOMAS E. HUGHES, *Superintendent of Maintenance*, Carnegie-Illinois Steel Corporation, Duquesne, Pennsylvania

2ND VICE-PRESIDENT, FRANK E. FLYNN, *District Manager*, Republic Steel Corporation, Warren, Ohio

TREASURER, C. L. McGRANAHAN, *Assistant General Superintendent*, Jones and Laughlin Steel Corporation, Pittsburgh, Pennsylvania

SECRETARY, J. L. MILLER, *Assistant Chief Combustion Engineer*, Republic Steel Corporation, Cleveland, Ohio

PAST PRESIDENTS: JULIUS A. CLAUSS, *Chief Engineer*, Great Lakes Steel Corporation, Ecorse, Michigan

C. CLARKE WALES, *Vice-President*, Hamilton Bridge Company, Ltd., Hamilton, Ontario, Canada

HONORARY DIRECTORS: JAMES FARRINGTON, *Electrical Superintendent*, Wheeling Steel Corporation, Steubenville, Ohio

A. C. CUMMINS, *General Superintendent*, Youngstown District, Carnegie-Illinois Steel Corporation, Youngstown, Ohio

WALTER H. BURR, *Electrical Superintendent*, Lukens Steel Company, Coatesville, Pennsylvania

DIRECTOR-AT-LARGE, P. F. KINYOUN, *Combustion Engineer*, Bethlehem Steel Company, Lackawanna, New York

DIRECTORS: FREEMAN H. DYKE, *Superintendent Blooming, Bar, and Hot Strip Mills*, Wheeling Steel Corporation, Steubenville, Ohio

A. R. DIBBEN, *Assistant Electrical Superintendent* Youngstown Sheet and Tube Company, East Chicago, Indiana

GEORGE C. PFEFFER, *Superintendent of Power*, Florence Pipe Foundry and Machine Company, Florence, New Jersey

W. J. WILSON, *Chief Electrician*, American Cast Iron Pipe Company, Birmingham, Alabama

I.N. TULL, *Electrical Superintendent*, Republic Steel Corporation, Cleveland, Ohio

STEPHEN M. JENKS, *General Superintendent*, Gary Works, Carnegie-Illinois Steel Corporation, Gary, Indiana

L. J. GOULD, *Assistant Chief Engineer of Construction*, Bethlehem Steel Company, Bethlehem, Pennsylvania

R. S. SHOEMAKER, *Lubrication Engineer*, American Rolling Mill Company, Middletown, Ohio

C. H. WILLIAMS, *Assistant Chief Engineer*, Pittsburgh District, Carnegie-Illinois Steel Corporation, Pittsburgh, Pennsylvania

Managing Director
BRENT WILEY
Empire Building, Pittsburgh, Pennsylvania

IRON AND STEEL ENGINEER

JUNE • 1941

VOL. XVIII NO. VI

In This Issue

Application of Power Requirements to Main Roll Drives—By L. A. Umansky, Assistant Manager, Industrial Engineering Department, General Electric Company, Schnectady, New York.. 25

Discussion: Application of Power Requirements to Main Roll Drives—Presented by L. A. Wynd, J. H. Miller, G. E. Stoltz, W. E. Gutzwiller, and L. A. Umansky..... 32

Open Hearth Furnace Control—By M. J. Bradley, Leeds & Northrup Company, Philadelphia, Pennsylvania..... 35

Discussion: Open Hearth Furnace Control—Presented by E. C. McDonald, J. M. Brashear, Vaclav Gregor, and M. J. Bradley..... 44

Developments in Blast Furnace Gas Cleaning—By C. H. Glaser, Superintendent of Blast Furnaces, Carnegie-Illinois Steel Corporation, Youngstown, Ohio..... 46

Discussion: Developments in Blast Furnace Gas Cleaning—Presented by Gordon Fox..... 49

Water Requirements of Steel Plants—By L. N. McDonald, Jr., Fuel and Power Engineer, Carnegie-Illinois Steel Corporation, Youngstown, Ohio..... 51

Systems and Equipment for Steel Mill Water Distribution—By H. M. Graham, Dravo Corporation, Pittsburgh, Pennsylvania 55

Effect of Water Upon Equipment and Product in the Steel Plant—By H. H. Shakely, General Master Mechanic, and C. J. Wyrough, Superintendent, Fuel Efficiency and Combustion Department, Jones and Laughlin Steel Corporation, Pittsburgh, Pennsylvania..... 59

Corrosion and Scale Formation in Steel Plant Water Supply—By E. W. Butzler, Hagan Corporation, Pittsburgh, Pennsylvania 64

Discussion: Water Requirements of Steel Plants; Systems and Equipment for Steel Mill Water Distribution; Effect of Water Upon Equipment and Product in the Steel Plant; and Corrosion and Scale Formation in Steel Plant Water Supply—Presented by K. M. Patterson, E. W. Trexler, W. T. Case, L. F. Coffin, E. W. Butzler, H. H. Shakely, L. N. McDoanld, Jr., Harry Finik, W. P. Hill, Isaac Harter, Jr., and H. M. Graham..... 68

Latest Design and Equipment for the Industry..... 81

Items of Interest..... 94

Index to Advertisers..... 14

Published Monthly by

ASSOCIATION OF IRON AND STEEL ENGINEERS

Entered as second-class matter January 25th, 1924, at Pittsburgh, Pa., under the Act of March 3rd, 1879

Statements and opinions given in articles and papers appearing in "Iron and Steel Engineer" are the expressions of contributors, for which the Association of Iron and Steel Engineers assumes no responsibility.

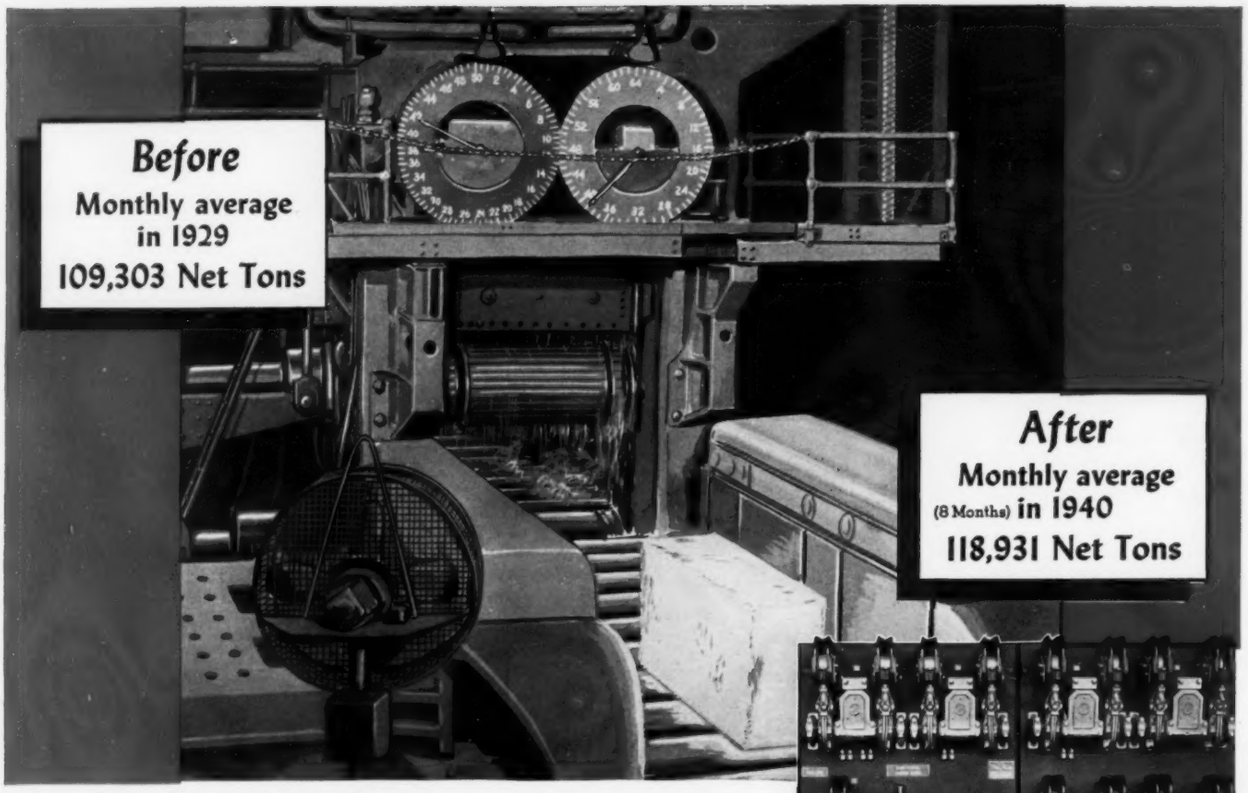
Copyright, 1941, The Association of Iron and Steel Engineers

Single Copy Foreign Prepaid $2.00 Single Copy $1.50

Subscription price in U. S. & Canada.....$ 7.50 per year

Subscription price in foreign countries.....$10.00 per year

PLASTIC BINDING U. S. PATENT NO. 1970285 LICENSE NO. 50



MODERNIZATION

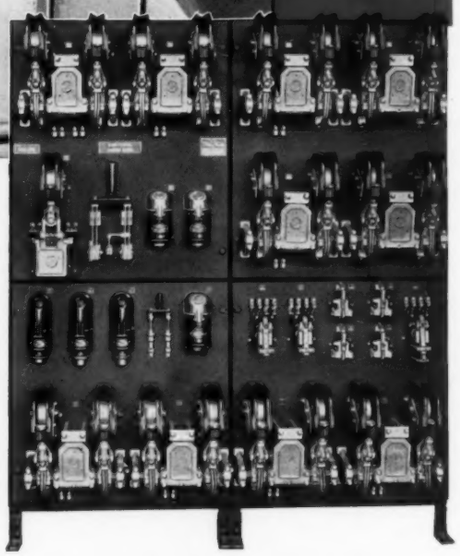
ups Production over 9600 Tons per month

IN THE plant of a prominent steel company, the 44″ blooming mill set a record of 109,303 tons monthly average in 1929. Modernization a short time ago increased production to approximately 118,931 tons monthly average . . . or a gain of 9628 tons per month.

Modernization consisted of new open hearths, increased soaking pit capacity, new heating practice as well as mechanical and electrical improvements on the 44″ mill. New EC&M Controllers were applied on all auxiliary drives—tables, sideguards, screwdown, manipulators, etc.—of this mill.

Contributing to the increased production are the EC&M LINE-ARC Contactors used on the new mill controllers. The arms of these contactors are 50% *lighter in weight* and *operate almost twice as fast as previous contactors.* With rolled steel for the magnetic circuit and light-weight alloys for the moving parts, these LINE-ARC Controllers are *lightning fast* in response to the operator's manipulation of the master switch.

Combined with Time-Current (load-controlled) Acceleration Relays, EC&M LINE-ARC Contactor Controllers are the logical choice for industry's direct current motor drives. Ask for Bulletin 925 describing them. The Electric Controller & Mfg. Co., 2700 East 79th St., Cleveland, Ohio.



Typical EC&M Mill Auxiliary Magnetic Controller

NEW CONTACTORS
almost twice as fast as those on previous controllers

FOR FAST OPERATION — Specify EC&M LINE-ARC CONTACTOR CONTROL

Application of POWER REQUIREMENTS to Main Roll Drives

By L. A. Umansky, Assistant Manager
Industrial Engineering Dept.
GENERAL ELECTRIC COMPANY
SCHNECTADY, NEW YORK

Presented before A. I. S. E. ANNUAL CONVENTION
CHICAGO, ILLINOIS, SEPTEMBER 24-27, 1940

▲ THE American steel industry is not yet using mercury arc rectifiers to any large extent. One 1000 kw. unit was installed in 1937 to supply 250 volt constant potential power in a wire drawing plant; another unit of the same rating was put in service elsewhere a few months ago; and a third rectifier, 1500 kw., 250 volt, also for constant potential power supply, has been just ordered.* In addition to this, two 3500 kw., 600 volt units are being built for a hot strip mill.

On the other hand, the European steel mills have been using rectifiers, both for d-c. auxiliary power and for main roll drives for 15 years or more, and their use is spreading. It is, therefore, pertinent for us to analyze the reasons for this difference in practice. Have we missed an opportunity? Or are the basic conditions sufficiently different between our country and abroad to explain this divergence of practice in this field?

In the first place, let us understand clearly that an arc rectifier, as a piece of equipment, is at least as fully developed in the United States as in Europe. Such improvements as the single anode tank, grid control, etc., are but few of the contributions made by American engineers. 600,000 kw. of rectifiers are used in the transportation industry on this continent, including high capacity units at high voltages, such as 600, 1500 and 3000 volts. The electro-chemical industry in the United States and in Canada employs or has on order a total of over 1,100,000 kw. of rectifiers. Thus, American industry knows rectifiers, and produces them in any sizes which the steel mills may need.

The true reasons, as the writer sees them, why our steel industry has not employed rectifiers to a great extent are as follows:

a. The constant potential applications in our steel mills are ordinarily 250 volts, while in the electro-chemical industry the trend is towards higher voltages and all major applications have been made at 600 volts; in railroad practice the voltage is from 600 volts to 3000 volts. On the other hand, in many European steel mills, the d-c. power, even when employed for auxiliaries, is used at 500 volts. Since it is well known that the cost of a rectifier per kw. goes down as the d-c. voltage goes up, this fact alone explains a lot.

b. In the electro-chemical industry, with the large blocks of power used in the processes and with the cost of power comprising a large portion of the total cost of the product, the efficiency of conversion (higher with the rectifier) is of relatively greater importance than in the steel industry. For instance, it takes about 10 kwh. to produce electrolytically 1 lb. of aluminum. This

Figure 1—Shop view of a 1500 kw., 250 volt, 12 anode rectifier built for general d-c. power supply in a steel mill.

*Since this paper has been presented, 6 additional 250 volt rectifiers (one 1500 kw., four 1000 kw. and one 750 kw.) were ordered for steel mill service.

entire amount of power must be converted to direct current. Assuming an extremely low power rate of .3 cents per kwh., the cost of power will be .3 cents per lb. of the product which sells at, say 20 cents; *i. e.* the cost of power is about 15 per cent of selling price. On the other hand, the steel industry uses not more than 250 kwh. per ton of finished product, which sells, on the average, for $70 per ton. Even allowing a very high average power rate of .8 cents per kwh., the total cost of power is only $2 per ton of product, or only 3 per cent of the selling price; a large portion of this amount of power is used directly as a-c. power without conversion.

c. In railroad practice, the higher average efficiency of the rectifier (particularly including the periods of light loads) and the desire to have unattended substations were equally potent factors.

d. Our steel mills are always laying greater stress, and rightly so, on operating reliability than on efficiency of electric equipment. When a mill is operating at full rate, even an hour shutdown once in a month might be more expensive than the losses due to a few per cent lower efficiency of an a-c. to d-c. converting equipment. Not that a rectifier is necessarily less reliable, taken by itself, than a motor-generator set; but the steel mill personnel knows how to fix the latter when needed, while the rectifier is something with which they do not feel themselves familiar as yet. This is a matter of "psychological reliability" or lack of it—a potent argument until someone will break the ice.

It is reasonable to expect that the wider use of rectifiers will accomplish two things simultaneously: reduction of rectifier cost and elimination of this psychological obstacle.

WHAT TO EXPECT OF A RECTIFIER

From an application viewpoint, the rectifier is nothing but another form of a-c. to d-c. converting equipment. If we are to use it, we must gain on some of the following points more than we might lose on others, or we must gain on all of them. These points are:

a. First cost
b. Efficiency
c. Installation cost
d. Maintenance cost
e. Reliability
f. Effect on power system

We should analyze the use of rectifiers in steel mills from these several viewpoints.

RECTIFIERS FOR 250 VOLT POWER SUPPLY

While the application of rectifiers for furnishing 250 volt general power supply does not enter directly within the scope of this paper, a few remarks will be pertinent to the following discussion. Furthermore, some of the main drives might operate from this source.

a. The first cost of a 250 volt rectifier is still higher than that of a corresponding motor-generator set, including in both cases the necessary switchgear.

b. The efficiency of the rectifier is higher, particularly at light loads. The saving in power may in many cases justify the extra first cost.

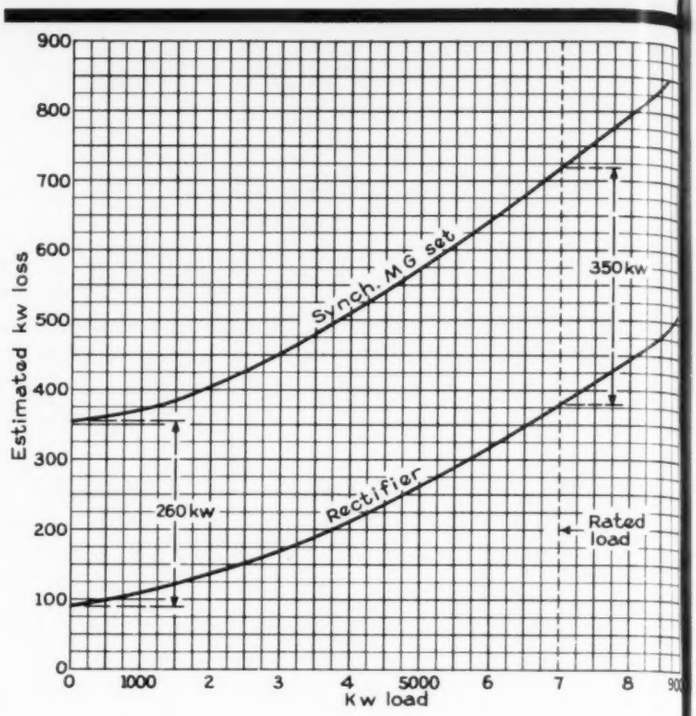


Figure 2—Comparison of losses in 7000 kw., 600 volt, motor-generator set and rectifier, with excitation of synchronous motor changed with load.

c. The cost of installation may be lower in case of the rectifier, particularly if the transformer is located outdoors, which is, however, not always possible.

d. It is too early as yet to discuss the relative reliability of a 250 volt rectifier and a motor-generator set. The rectifier units installed are operating very creditably; so do many hundreds of motor-generator sets.

e. The power factor of the rectifier is slightly lagging, as against the leading power factor of a motor-generator set. This is not always a handicap, since in most of our plants the synchronous capacity on the system is ample. However, if a new plant is built with rectifiers used throughout instead of synchronous motor-generator sets, this fact might constitute a problem.

A 250 volt rectifier, connected to the mill supply d-c. system, preferably should be equipped with grid control. If parallel operation with motor-generator sets on the same system is required, then this grid control with automatic voltage and load-division regulators becomes essential. If the rectifier is connected to an isolated d-c. bus, the grid control with a voltage regulator might also be desirable, as otherwise the a-c. system voltage fluctuations will be directly reflected in the d-c. system.

RECTIFIERS FOR CONSTANT POTENTIAL MAIN ROLL DRIVES

In this case, the power supply is maintained at a constant potential, and each drive is equipped with an individual starter (magnetic control). There are a number of such mills in existence; for instance, many

merchant and rod mills. The drives are usually of small or medium capacity (say, up to 1500 hp., 600 volt, more or less). Sometimes the same motor-generator set or sets are used to supply power to several mills; the diversity factor helps to reduce the capacity of the converting equipment. Magnetic control is not prohibitive in cost for drives of this size.

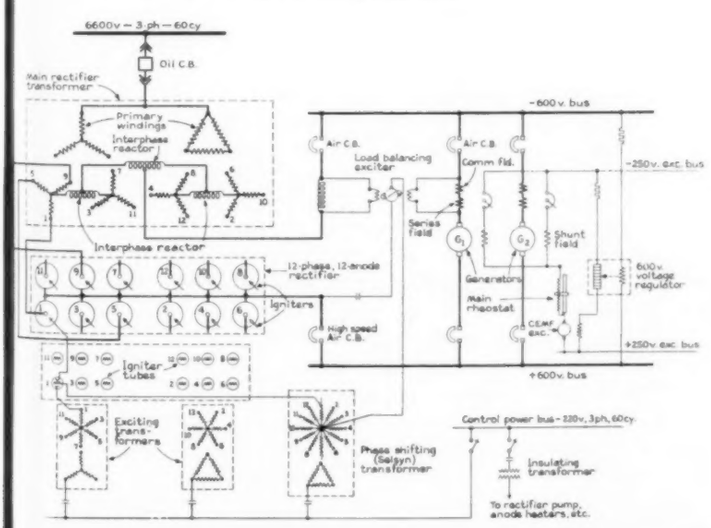
Rectifiers will fit such applications quite well. The cost, in the case of 600 volts, would be practically competitive with that of motor-generator sets. For the sake of voltage maintenance at the motors, some form of grid control would be essential. It can be readily provided. In fact, this is the best conceivable application of rectifiers in the steel industry.

RECTIFIERS FOR NON-REVERSING DRIVES REQUIRING WARD-LEONARD CONTROL

The second group covers such large non-reversing drives, like hot strip mills, where magnetic control for each motor is not desirable on account of its size, and where Ward-Leonard starting and stopping, and sometimes adjustable voltage is wanted. Drives with individual motors up to 5000 hp. are common; total capacity of the d-c. drives on one mill may be as high as 25,000–30,000 hp., with the capacity of the converting equipment as high as 18,000–21,000 kw. While Ward-Leonard starting (through grid control) is technically feasible, and has been used in Europe for such applications, we are rather reluctant as yet to use it indiscriminately in our mills of this type.

In the first place, the grid voltage control of a rectifier is obtained at the expense of distortion of the wave form of a-c. supply, and at the expense of the power factor; the latter goes down in practically the same proportion as the voltage. Not many power systems would care to have an equivalent of a 20,000 kva. load

Figure 3—Simplified diagram of power and control circuits for hot strip mill, with two 3500 kw. rectifiers in parallel with six 1500 kw. generators.



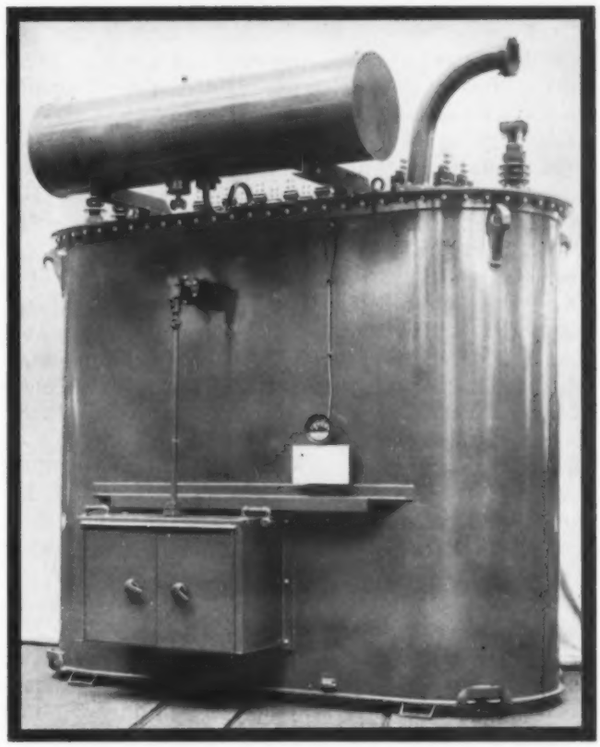


Figure 4—View of 6600 volt, 60 cycle transformer used with each 3500 kw. rectifier to supply power to a hot strip mill.

started at zero power factor. The contingent wave form disturbance (resulting in high harmonics) is apt to interfere quite seriously with telephone communications. To minimize these conditions, on some European installations each of the several d-c. finishing mill motors of a hot strip mill is provided with a separate rectifier; thus the several motors can be started, one at a time. On the other hand, this means that a larger kw. capacity of the converting equipment is required. For instance, on a 56 in. hot strip mill built in Europe, each of the six 3000 hp. finishing mill motors is provided with a 2400 kw. rectifier; the total converting equipment capacity is, therefore, 14,400 kw., while a similar mill in the United States, operating at 30 per cent higher speed, is amply provided with two 6000 kw. motor-generator sets connected to a common bus, an arrangement substantially lower in the first cost.

A rectifier, operating at greatly reduced voltage by grid control, unless specially designed for it with utmost care, is apt to cause more concern from the viewpoint of arc backs than one without this feature.

When conditions are just right, rectifiers may be well considered even for very large mills. For instance, a strip mill, built some 13 years ago, is to be widened and speeded up, requiring more power in driving motors. It has been estimated that the finishing stands, now supplied from three 3000 kw. motor-generator sets, will require an additional 7000 kw. capacity. This could be supplied by a motor-generator set or by a rectifier. A comparative study was made.

First of all, the conversion efficiencies were compared. Instead of dealing with efficiencies at various loads, and then debate as to what represents "an average load," the kw. losses of conversion were plotted directly against the kw. load of the conversion unit (see Figure 2). The losses of the motor-generator set were estimated on the most favorable basis for it; with the synchronous motor excitation automatically adjusted as a function of load. In spite of this reduction of running light losses of the set, the rectifier losses are about 260 kw. lower at no-load, and are about 350 kw. lower at full load of 7000 kw. With this difference of losses remaining almost constant at all loads in this case, it can be safely stated that this difference is about 300 kw., on the average, regardless of fluctuation of load. If the mill is to operate, say, 7000 hr. per year (about 73 turns per month), the use of a rectifier can save over 2,000,000 kwh. each year. At .5 cents per kwh. this saving is $10,000 annually. If the power rates are higher or lower, the saving is proportionally greater or smaller. Thus, there was in this case a proper background to consider a rectifier. For several reasons two 3500 kw., 600 volt rectifiers, each with its own transformer, were chosen in preference to one 7000 kw. unit.

The presence of original motor-generator sets eliminated the need of using either the grid control, or magnetic starters for starting the several finishing mill motors. Generators only are to be used for Ward-Leonard starting. After the bus voltage is brought to the pre-selected value, the rectifier breakers automatically close and from then on the rectifiers and the generators are to divide the load. Likewise, for stopping the mill, the rectifier breakers are tripped and the motor-generator sets are used for regenerative braking.

It may be of interest to note the salient points of the switching and control arrangement. The diagram (Figure 3) shows, for simplicity's sake, only one 3500 kw. rectifier and only two d-c. generators. To eliminate as far as possible any telephone intereference, each rectifier is built as a 12 phase unit. The transformer is built with two cores, each having a 3-phase primary and two 3-phase secondary windings, as shown. With one primary winding Y connected, and the other delta, the necessary phasing is provided.

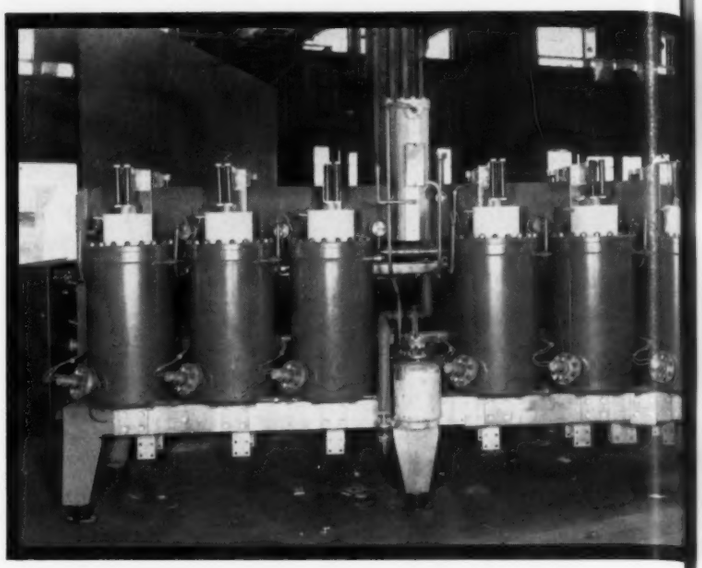
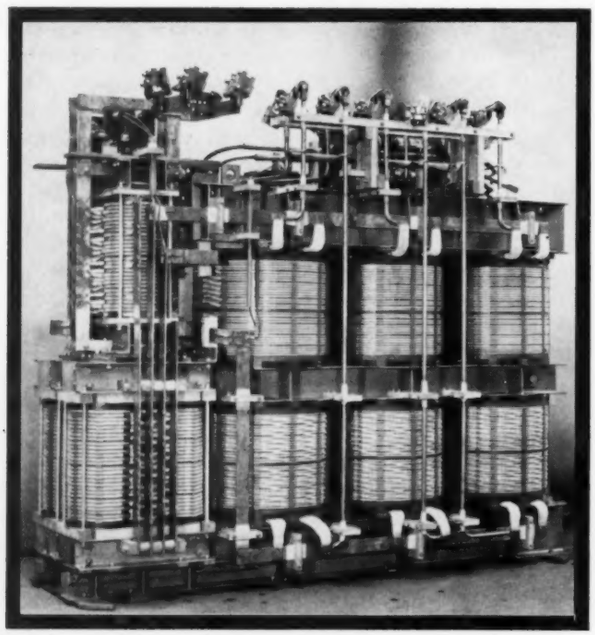


Figure 6—View showing one of two 3500 kw., 600 volt rectifiers supplying power to a hot strip mill.

Figure 5—This view shows the un-tanked 6600 volt 60 cycle transformer of Figure 7 used with each rectifier.



The primary windings are equipped with several taps. In this manner d-c. voltages lower than 600 volts can be obtained when needed. Tap changing under load has not been provided, as it is not essential for this application.

The rectifier is composed of 12 single anode tanks, of ignition type. The le firing tubes are excited from two small exciting transformers. The grids of the firing tubes are energized by a phase shifting transformer, which is nothing but a small selsyn machine, the rotor of which can be readily rotated to give the needed phase angle. By controlling the potential of the neutral of this selsyn, the grid control is obtained and the mean d-c. rectifier voltage can be adjusted within 10–15 per cent, or more.

The grid control is wide enough to compensate for the inherently dropping voltage-load regulation of the rectifier and for the expected voltage fluctuations on the a-c. power system.

After the finishing mill motors have been brought to speed by generator voltage control, the voltage at the 600 volt bus is maintained constant by a voltage regulator. The several generators are, as usual, provided with differential series fields, insuring even load division between these machines. After the rectifier breakers close, the current output of each rectifier is then compared with that of a generator. These two currents (or, rather, a small portion of each) are used to excite a load

balancing exciter which controls the grid potential. In this manner, the rectifiers and the generators will divide the total load in proportion to their rating, or in any other desired proportion. Since the grid control is free from any inertia, and, therefore, time lag, and the load balancing exciters are of the amplidyne type, *i. e.* of extremely high rate of response, the whole load balancing control is inherently fast acting and should be very effective.

It is of equal interest to observe how well the rectifier equipment will fit physically into a conventional hot strip mill motor room. The two sketches diagrammatically show the plan (Figure 7) and the cross section (Figure 8) of such a room.

In the first place, we should note that the rectifier does not save much floor space as compared with a motor-generator set, particularly if we keep in mind the rectifier transformer. A hot strip mill motor room seldom has an outside wall beyond which the transformer could be economically installed as an outdoor unit. Since the leads between the transformers and the rectifiers on the one hand, and between the rectifiers and the main 600 volt bus should be made as short as possible, it has been found most practicable in this case to locate the rectifiers in line with the motor-generator sets, *i. e.*, opposite the mill motors, and the transformers—in the basement, beneath the rectifiers. The transformers are made water cooled, located in a vault.

Thus, the two 3500 kw. rectifiers occupy a somewhat longer but narrower space than a 7000 kw. motor-generator set would take. The transformers take approximately the space of the motor-generator foundation. The cost of the latter is saved. Ventilating requirements of the whole motor room are reduced. The total installation costs are apt to be somewhat lower.

The performance of this first American installation of rectifiers for main roll drive will be watched by all of us with great interest.

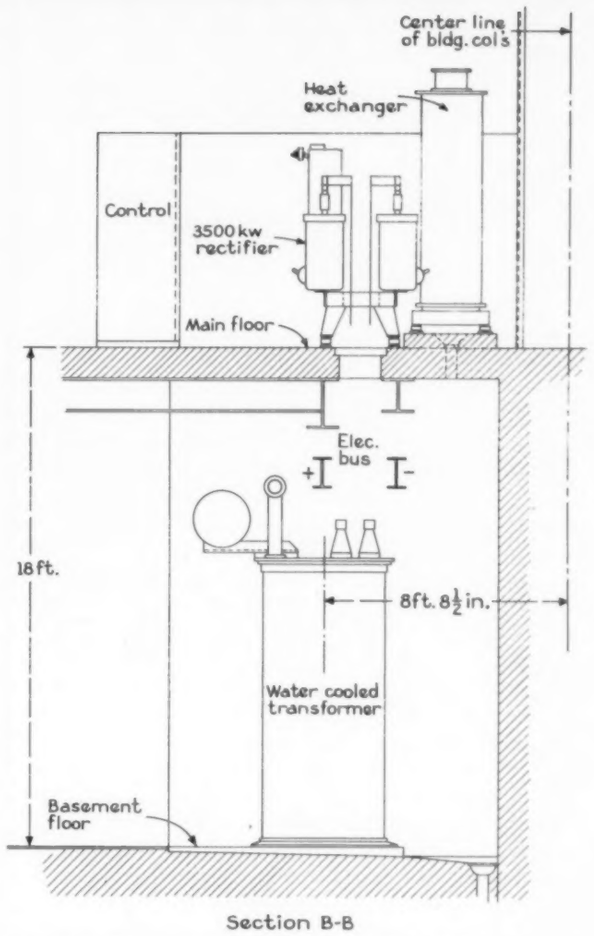


Figure 8—Cross section through the motor room shown in Figure 7. The rectifiers are set on the main floor, with the transformers mounted beneath them.

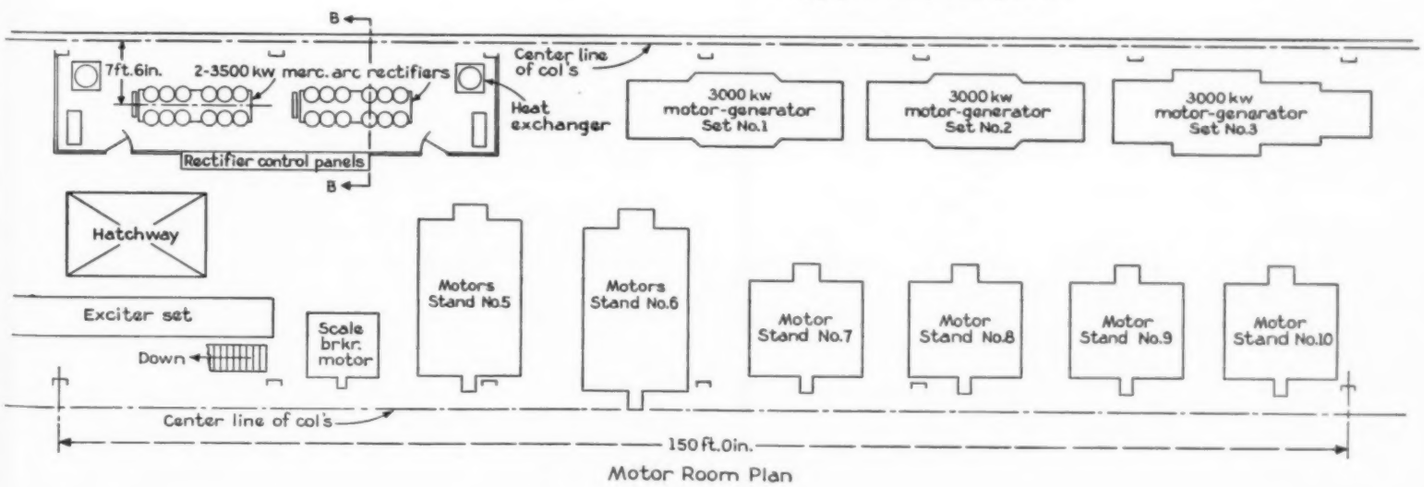
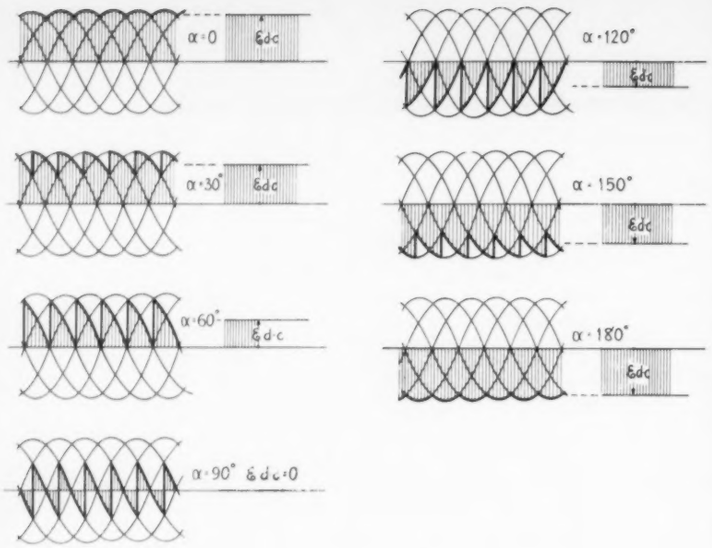
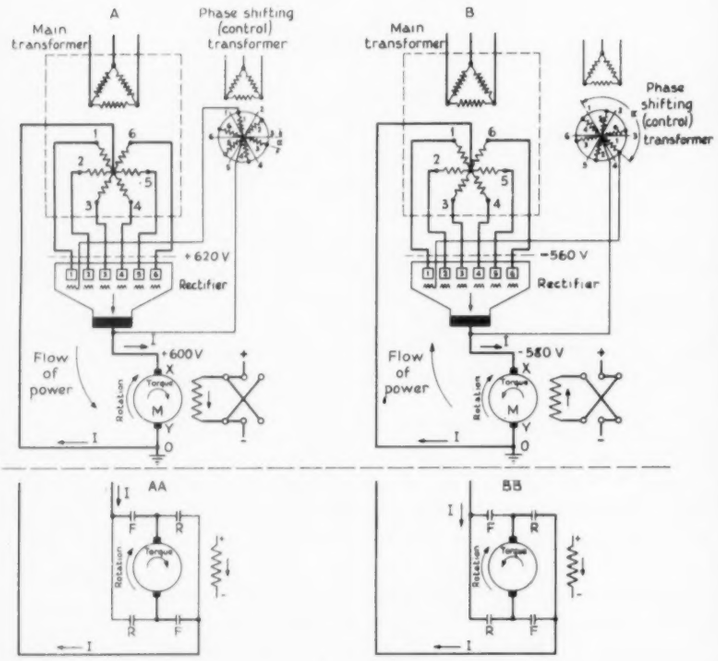
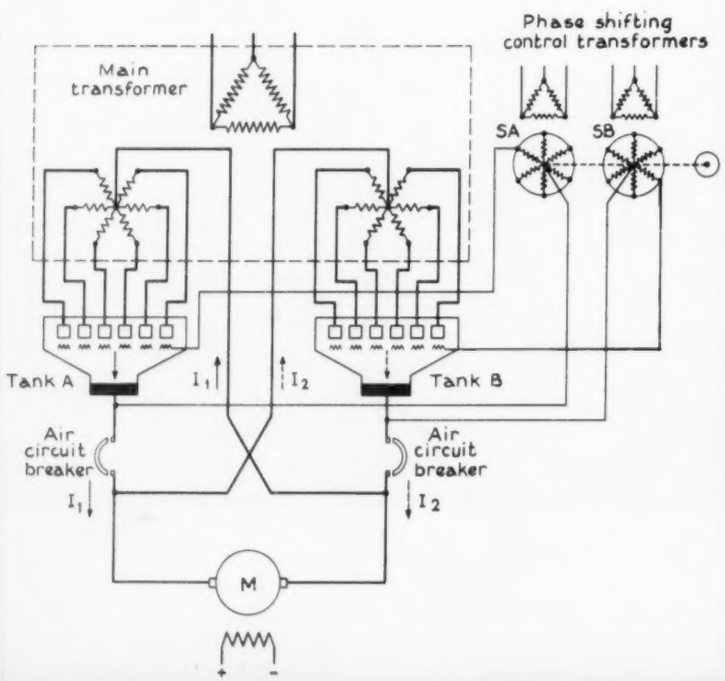


Figure 7—Floor plan of motor room of mill using two 3500 kw. rectifiers in addition to six 3000 kw. generators to supply finishing train power.







RECTIFIERS FOR START-STOP AND REVERSING DRIVES

The third group of main roll drives (as far as the rectifiers are concerned) covers the mills where Ward-Leonard starting and stopping (including regenerative braking), as well as reversing, are frequently and repeatedly used. Cold strip mills, of reversing and tandem type, fall in this class. Reversing hot mills, like blooming, plate, rail and structural, etc., represent the extreme end of this line. Rectifiers can be used even in such cases, technically speaking, but many difficulties need be overcome. In the first place, we must see whether regenerative braking can be obtained and, if so, by what means.

One should remember that a rectifier is essentially a one-way valve for the flow of current. Hence, if we merely cut down the rectifier voltage, say by grid control, the mill motor, even though generating a higher cemf. voltage than that of the rectifier, will not be capable of reversing the flow of current. Hence, no pumping-back of power will take place, and the regenerative braking will not be available, unless something else is resorted to.

We should realize, however, that a power flow can be reversed by maintaining the same direction of current, but by reversing the polarity of voltage. We are not used to this method and it takes some mental effort to comprehend it, but this is exactly what is done with a rectifier drive.

Figure 9 (top)—Sequence chart showing effect of grid control on d-c. voltage supplied by a rectifier.

Figure 10 (middle)—Elementary diagrams showing connections for starting and reversing a d-c. motor supplied with power from a rectifier.

Figure 11 (bottom)—Cross-connection diagram for d-c. mill motor for frequent reversing. Armature connections are not interrupted, nor is the motor field reversed.

Figure 10-A shows a conventional rectifier feeding a mill motor *M*. For the sake of clarity, a six phase multi-anode tank is indicated, but, of course, any other number of phases, or a single anode, multiple tank, ignitor type rectifier can be just as well used.

Grid control is shown as provided by a phase shifting control transformer. As noted previously, the latter may be built as a selsyn machine; *i. e.*, broadly speaking, as a miniature induction voltage regulator. By turning the rotor of this selsyn through a 180 degree angle, as shown on Figure 10-A, one can control the mean d-c. voltage of the rectifier in stepless fashion, as is graphically shown on the sequence chart, Figure 9.

The mill motor is separately excited from any available source and, for simplicity's sake, no field rheostats are shown, although quite obviously they can be employed. By shifting the control transformer within the 0–90 degree angle the rectifier voltage is adjusted between its maximum and zero.

Now, assume that we want to stop the motor by regenerative braking. Suppose we move the selsyn rapidly from 0 to 90 degrees. This will reduce the rectifier voltage, but, as was pointed out, will not produce any pump-back current. No current will flow at all, since the rectifier voltage is less than the motor emf. The result is as if the armature circuit were actually opened.

Now, since the armature circuit is, in effect, open we can safely reverse the motor field (see Figure 10-B). Since the motor still runs in the same direction, this will reverse its emf.; instead of having on the brush X a potential of, say, +600 volts to ground, we will get on the same brush a potential of, say, −580 volts to ground. (We assume, for the sake of clarity, that the brush Y is grounded, although this is not at all essential for the performance.)

At the same time the selsyn has been moved to a practically 180 degree position. This has the effect of reversing the rectifier anode polarity. Say, the mean anode d-c. potential is −560 volts to ground. Thus, a current will flow through the rectifier in the same direction as previously (see arrow in figure), since the current flows from a "less negative" point (−560 volt) to a "more negative" point (−580 volt). Since the motor armature voltage has been reversed, it is obvious that in spite of the unidirectional current the power flow has been reversed. The motor pumps back. The rectifier converts this power and sends it back into the a-c. system. The rectifier acts as an inverter.

As the motor slows down, its cemf. is reduced and the current will drop down, unless we gradually move the phase shifting selsyn back from 180 degrees to 90 degrees. In this manner we can effectively stop the motor as if by Ward-Leonard control. By moving then gradually the selsyn from 90 degrees back to 0, the motor will be reversed and brought up to speed in the opposite direction.

Instead of reversing the motor field, we can reverse its armature circuit, as shown on Figures 10-AA and 10-BB. The reversing contactors reverse the circuit while the selsyn is moved to the 180 degree position; *i. e.* when there is no flow of armature current. One must remember that in either one of the above cases, the armature circuit has been, in effect, interrupted; *i. e.* the motor torque has not been maintained during the transition period.

The described arrangement has been employed in several European steel mills. If one wants it badly enough here, there is no reason why he should not get it, taking the poorer power factor during the starting and braking periods, the reversing contactors, etc., into the bargain. We should hardly recommend it for such drives as cold strip mills or anywhere where starting, regenerative braking, and stopping are frequent.

In order to eliminate the reversal of either the motor armature circuit or its field, the European practice has evolved another, more elaborate arrangement, as shown on Figure 11. It involves the use of two rectifier tanks (or of two sets of single anode tanks) and of a transformer with a double secondary winding, one per rectifier. The arrangement is known as the "cross connection."

Each of the rectifiers has its own phase shifting control transformer. The latter are set with phases 180 degrees apart, and are operated through a common shaft. Thus, as we will presently see, when the tank A acts as a rectifier, the tank B is set up to be ready to act as an inverter, and vice versa.

For one direction of rotation of the motor, say clockwise, the tank A supplies power to it in a regular manner, with the selsyn set between 0 and 90 degrees. The motor current I_1 flows as indicated. The grid control is such that at the same time the d-c. voltage of the inverter tank B is higher than the motor emf., and, of course, higher than the d-c. voltage of tank A. Hence, during this period the tank B is not active at all.

Now let us move the selsyn shaft rapidly from 0 to 90 degrees. As we have observed previously, this will reduce the voltage of rectifier A below the motor emf. and this will, in effect, cut the current I_1 off (although the breakers stay closed all the time). While the selsyn SA moved from 0 to 90 degrees, the selsyn SB moves (electrically speaking) from 180 degrees to 90 degrees; this sets the tank B for the inverter operation. As soon as the d-c. voltage of tank B is less than that of the motor emf., the pump-back begins, as indicated by arrows I_2. The motor is brought to rest, with both selsyns set at 90 degrees. By moving the selsyn SA from 90 to 180 degrees (which is a 90–0 degree electrical movement for selsyn SB), we now cause the tank B to act as a rectifier, supplying power to the motor running now in the clockwise direction; the tank B is now standing by, ready to act as an inverter when we slow down the motor preparatory to reversing it again.

If this arrangement is used for a reversing drive, operating an equal length of time in either direction, the rating of each rectifier tank and of each transformer secondary winding should be made at least 71 per cent of the motor rating, from heating viewpoint alone. Peak loads may force the use of two full capacity tanks.

The effect on the price is obvious. If it is still difficult in many cases for a conventional rectifier equipment to compete on price with a motor-generator set, the use of the cross connected arrangement is apt to make the competitive situation far less attractive for the rectifier.

Several relatively small installations of such cross-connected rectifier drives were made in Europe. They prove only that the rectifiers can be made to work even under such service. However, these examples fail to prove the wisdom of these applications, at least under our conditions.

CONCLUSION

In case of main roll drives, the application of rectifiers would hardly be considered at all, if it were not for their better efficiency, or, to put it differently, for their lower operating losses. In some cases this saving, as we have seen, amounts to a very sizable sum of money.

The floor space requirements and installation costs are not necessarily or always reduced with the rectifiers. In many instances the rectifiers and their associated transformers must be located quite close to the main drives. There may be no "outdoor wall" in the motor room, beyond which to set the transformer. The problem of suitably locating it, without introducing a fire hazard, must be solved in each case. Pyranol filled

transformers represent one possible solution; but this increases the first cost and makes the competition with the motor-generator sets more difficult.

A main drive motor room, whether provided with motor-generator sets or rectifiers, contains in either case some rotating equipment. If the latter requires an attendant, then the use of rectifiers cannot give us an "unattended station." Still, it is fascinating to obtain an a-c. to d-c. converting equipment without rotating machinery.

The operating characteristics of rectifiers for certain types of main drives can be made fully comparable with those of motor-generator sets, and practically as good as the latter. However, they are not any better.

The operating personnel will soon become familiar with rectifiers, as they did with any other electrical equipment. As the steel mill engineers have mastered the up-to-date cold strip mill control, they will take the rectifiers in their stride.

Summing up, the rectifier is a new, somewhat more efficient tool for converting a-c. supply into d-c. power. For many applications, it fits quite well and has definite merits. Hence, it is reasonable to expect its gradual spread in certain fields of main roll drives. This field has now certain limitations. Experience and developments will gradually widen these limits. We should follow this path of development with optimism, but without haste.

DISCUSSION

PRESENTED BY

L. A. WYND, *Electrical Superintendent,* Republic Steel Corporation, Chicago, Illinois.

J. H. MILLER, *Electrical Superintendent,* Wisconsin Steel Works, International Harvester Company, Chicago, Illinois.

G. E. STOLTZ, *Manager,* Metal Working Section, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania.

W. E. GUTZWILLER, *Sales Engineer,* Rectifier Division, Allis-Chalmers Manufacturing Company, Milwaukee, Wisconsin.

L. A. UMANSKY, *Assistant Manager,* Industrial Engineering Department, General Electric Company, Schenectady, New York.

L. A. WYND: Four years ago the first mercury arc rectifier to be used in a steel mill on this side of the Atlantic was placed in commission at Republic Steel Corporation's new wire mill at South Chicago.

Due to its efficiency this 1000 kw. unit has furnished 250 volt d-c. for about $6000 less than a motor-generator set of the same size in similar service.

At the Annual Convention in Cleveland you were given a brief summary of the operating experiences up to that time. Total expenses over a two year period were $237.00.

Since then it has been necessary to replace a cracked main anode insulator. This repair was made during a regular week-end shut down in a period of low production. The unit was taken out of service at 4 P.M. Friday, repaired, and placed back in service on its regular load at 7 A.M. the following Monday. Total cost of the repair was $500.00.

We believe the cracking of this insulator was caused by a jar from a skull cracker located about 500 ft. north of the wire mill substation. No other trouble has been experienced with the unit.

One service interruption occurred when a service water valve was accidentally closed. In this case the automatic feature designed for water failure shut the rectifier down. Service was restored in ten minutes. This interruption was also mentioned in the Cleveland discussion.

The principal reason for rectifier development and extensive use in Europe is that of operating efficiency, and reliability. Power costs are high over there, and that more than anything else is the reason why railroads and industries in Europe have gone in so strongly for these units.

There may have been a time in the history of American industry where conversion costs were not important. That is not true today and the rectifier will do its share toward lowering these costs if given a chance.

I have been informed that the installation of two 3500 kw. rectifiers which are being added to a hot strip mill in this country, are expected to save two million kwh. per year in conversion costs.

As to the five points mentioned in comparing rectifiers with motor-generators, our experience is, that initial cost is the only one not better. Greater first cost is soon wiped out by the higher efficiency where load factor is 50 per cent or lower and power costs are around 6 to 7 mils.

As to substation attendants, our experience has been that we can practically forget about the unit. It has operated from the beginning in an unattended station. 28,000 hr. of operation of this unit was reached August 29, 1940.

In closing I want to express the earnest belief that rectifiers, if applied intelligently, will earn substantial sums for any company adopting them.

J. H. MILLER: In considering a new tool, there is plenty of room for argument both pro and con. These arguments, I believe, have been given impartial coverage in this paper and I would, therefore, submit my observations as one of the uninitiated in the use of this new device.

Although the possibilities of the rectifier itself are unlimited, the field for its use in the steel industry at the present has certain very marked limitations as a competitive means of converting alternating current to direct current. The most favorable condition for its installation being that of constant potential drives at 600 volts, direct current or above, retards consideration of rectifiers as a source of 250 volts, d-c. Here, with our present capacity of motor-generator sets and converters, is the real opportunity for proving a new conversion device, and any additional capacity at 250 volts, d-c. should be weighed very carefully with a view to taking advantage of the rectifier's higher efficiency. However, main roll drives have no standby generators available and, therefore, cause the question

of reliability to outweigh quite a gain in higher efficiency, lower maintenance, and in some cases a lower first cost.

Since, then, the question of reliability stands out for consideration, let us discuss this, assuming a rectifier installed under the most favorable conditions. We have seen, as in the case of individual drives for runout tables, that with a given set of conditions, the present-day d-c. machine with its brushes, commutator, and rotating parts is not so bad, and often proves to be the most economical drive. With the comparatively recent improvements in the design of commutators on direct current machines, I wonder if there is not more than a "psychological reliability" in question. As Mr. Umansky points out, we are familiar with motor-generator sets and converters and, although it is not impossible that this familiarity is breeding contempt, let's have a look at the rectifiers. This rectifier, remember is installed under the most favorable conditions and has the advantages of equal first cost, higher efficiency and lower installation cost. No one as yet can prophesy what the maintenance cost will be; a mercury condensation pump, an oil immersed vacuum pump, water supply and circulation, insulating bushings that must hold vacuum—it is reasonable to expect that these will require some maintenance. Although it sounds very simple, the maintaining of a vacuum to the thousandths of a millimeter could become quite complicated, and once this vacuum is completely lost, it would very likely require degassing or baking out, with considerable delay. Cooling water is not only essential, but water heaters are provided to keep the water from becoming too cold lest it cause a backfire or loss in efficiency. Of course, this only serves to prove Mr. Umansky's point that it is a "psychological reliability," but these points cannot be overlooked when "steel mill reliability" is concerned.

In conclusion, the installations mentioned in this paper are a credit to the gentlemen who installed them as well as to the concerns which they represent, and no doubt there will be more applications presented where the rectifier is indicated, and, with equal engineering judgment, will be applied. A more efficient tool properly applied is a very desirable thing and I would only repeat Mr. Umansky's closing thought, in that it should be pursued with optimism, but without haste.

G. E. STOLTZ: The use of mercury arc rectifiers is relatively new in the steel industry and it is of considerable interest to the engineers of this industry to have a statement of the advantages and limitations of this new device. In the paper just presented Mr. Umansky has given us this information in a very clear and concise manner.

Previous to 1937 mercury arc rectifiers were built with 6 or a multiple of 6 anodes in one tank. With this construction all anodes were exposed to ionized gas at all times. To prevent the idle anodes from arcing back, the space and baffles between each anode and the common cathode was such that a voltage drop of 22 to 30 volts was obtained between electrodes.

Early in 1937 the first ignitron mercury arc rectifier was installed in a coal mine owned by the Union Collieries Company of Pittsburgh, Pa. This rectifier had a capacity of 300 kw. at 275 volts d-c. The basis of this design is the provision of a means of ionizing the gas between electrodes at the instant a particular anode begins to transport current. When this particular anode discontinues carrying current, the gas is de-ionized. The fact that the idle anodes are in de-ionized gas makes it possible to bring them closer to the cathode and reduce the arc drop voltage to approximately 16 to 18 volts. This effects a substantial increase in efficiency, and it was just this step that made the mercury arc rectifier competitive with the performance of motor-generator sets of fairly large capacity at 250 volts.

Mercury arc rectifiers could have been introduced in the steel industry either to operate the large mill equipment that usually requires 600 volts or for 250 volt d-c. auxiliary power. While the rectifier has demonstrated that it is a very reliable device, it was only natural for the steel industry to install the first unist for 250 volt mill supply. Any trouble that might have occurred with these first units need not cause serious interruption of service as other converting equipment in parallel with the rectifier could carry on.

Since the ignitron rectifier has been developed, serious consideration has been given to its installation in the steel industry in preference to motor-generator sets.

As reported in Mr. Umansky's paper a single tank unit has been in operation in the steel industry for several years and an ignitron type was placed in operation in the steel industry during this calendar year, another has been purchased and there is every indication that the rectifier will be used very largely instead of motor-generator sets particularly on applications requiring constant voltage d-c. supply.

On variable voltage applications where regeneration is obtained such as is obtained on reversing blooming mills or on cold mills that are brought to rest quickly enough to cause the motors to regenerate into the synchronous motor-generator sets, the mercury arc rectifier at present is not a practical device.

To use a rectifier for this application it would be necessary to employ reversing switches or to have a duplicate set of tanks, one group being used to convert alternating current to direct current, and a second group to absorb the direct current regenerative energy and feed it back into the a-c. supply. This materially increases the cost of the equipment and further than this a rather complicated grid control would be required. With the present state of development of the mercury arc rectifier motor-generator sets are better adapted to this type of service and no doubt will be continued to be used for the time being.

W. E. GUTZWILLER: The paper is the first one presented before the Association which discusses the possibilities of rectifiers for the four major power conversion jobs in modern steel mills. There is a definite need for information of this kind at this time. The author is to be congratulated for the simple and logical manner in which he discussed this subject.

Motor generators have given a good account of themselves in the past. However, they have about reached their limits as regards efficiency and performance. If we are to make progress, we cannot be satisfied with what we have today, but must strive for still greater conversion economy and better performance.

The merucry arc rectifier, although firmly established in the railway and chemical fields, is still a new conver-

sion tool for steel mills, and has a long way to go. Unquestionably, as more experience is gained in its use in mills many improvements and simplifications can and will be made. While the conversion efficiency of motor generators in the last few years has been improved only by fractions of a per cent, the rectifier efficiency, due to the recent introduction of the single-anode rectifier, has shown an improvement of 3 to 4 per cent at 250 volts, when compared with the multiple anode rectifier tank.

We all have to admit that direct current is a necessary evil in the manufacturing of steel, because it cannot be economically generated and transmitted in large blocks. Its use in a mill therefore requires some sort of conversion at or near the load, which appreciably increases power and operating cost. The use of a rectifier as a converting device simplifies the conversion problem by eliminating the transformation of electrical power into mechanical power which is taking place in the motor generator set. The rectifier substation thus approaches that of a transformer substation.

With the advent of the single-anode rectifier, power conversion at 250 volts for mill supply is bound to become the most attractive field for rectifiers. It is in this field where installations have already been made, and several years of experience been gained with one rectifier unit.

The paper draws a comparison between conventional rotating type conversion equipment and rectifiers on the four major points of cost, efficiency, reliability and effect on power system. Besides these major points there are a number of other points worth considering here.

A number of large steel mills generate 25 cycle power and purchase 60 cycle power. Since rectifiers can be economically built to operate on either frequency, the rectifier has a distinct advantage over a motor generator where a converting substation can use either frequency, or where it is contemplated at a later date to permanently change the source of power from one to the other frequency. Dual frequency rectifier sets in such mills are therefore an extremely flexible piece of apparatus, rendering the future power planning simpler and enabling load dispatchers to transfer rectifier loads from one to the other power system, in order to reduce system peak demands. The extra cost to provide a 25 cycle, 1000 kw., 250 volt d-c., 6600 volt a-c. rectifier set for operation on 60 cycles is approximately 7 per cent of the price of a straight 25 cycle set.

While speaking of mills with 25 and 60 cycle power systems mercury arc rectifiers also provide means for changing power from one frequency into power of another frequency. They thus can perform a similar task as a rotating type frequency changer of the Scherbius type.

It is common practice in the larger mills to use an extensive 250 volt d-c. network for mill supply and to which converting substations throughout the plant are connected. Where substations of such a network are supplied from different a-c. sources, or from sources of different frequencies, their proper paralleling and load division sometimes becomes a problem. During local disturbances on the a-c. systems motor-generator sets may be overloaded or reversed and may feed back into the a-c. system. This condition is greatly simplified by the use of rectifiers, as reversal is not possible and the voltage can be controlled by means of the grids to prevent excessive overload. These characteristics make the rectifier ideal for unattended, automatic substations and permit their location remote from attended places such as ore and coal bridges.

The question of adequate a-c. switching equipment in the steadily growing power systems of large steel plants has been given a great deal of attention. The addition of large synchronous motor generator sets to these mills has not made the switching problem any simpler as such motors add to the value of the short circuit current of a-c. systems. Mercury arc rectifiers do not increase the short circuit currents, and if used in large numbers in a mill, savings in investment and maintenance of switchgear will result. Moreover, with the use of rectifiers the bumps on the power system caused by starting of large synchronous motor-generator sets are avoided.

Rectifiers and their transformers can be provided for water cooling without extra cost. If water cooled rectifier equipment is partly substituted for motor-generator sets in large mill motor rooms, the problem of cooling such rooms, the cleaning and washing of the cooling air is simplified because the total heat losses of motor-generator sets in motor rooms amount usually to as much as 45 per cent of the total machine losses. Furthermore, by such substitution the air temperature in the motor room would be lowered and the noise reduced, both of which would have a beneficial effect on the efficiency of the operators.

We agree that mercury arc rectifiers are not a cure-all for the conversion problems in steel mills. There are, nevertheless, countless cases where an investment in mercury arc rectifiers instead of motor-generator sets will bring greater returns to the user. There are many manually operated and attended 250 volt motor-generator substations, some 15 to 20 years old. Due to the growth of the mills, their location with respect to d-c. load may no longer be satisfactory. In such cases investments in modern automatic mercury arc rectifier substations which can be more economically supplied from one or more sources of a-c. power, seem to be justified. Likewise, as the paper has brought out, there is no reason why mercury arc rectifiers should not be used as a means for simplifying the conversion problem of future constant potential, non-reversing main roll drives, or as additions to existing plants now supplied from motor-generators but requiring increased capacity and speed.

L. A. UMANSKY: I want to thank all those who have taken part in this discussion and have commented on the paper. I have no basic exception to take to anything said by them.

In closing, I want to give full credit to the man who had the courage and vision to pioneer, in the United States, the application of rectifiers for the main roll drives. While in my paper, I did not mention the name of the steel company which will use the two 3500 kw. rectifiers on their hot strip mill, it is now generally known that this man is our friend, A. W. Duncan, of the Weirton Steel Company. All of us in this Association, manufacturers as well as operators, should be grateful to him for blazing this new trail. Progress is made by men who live today and visualize the tomorrow.

OPEN HEARTH

Furnace Control

By M. J. Bradley

LEEDS & NORTHRUP CO.

PHILADELPHIA, PENNA.

Presented before A. I. S. E. ANNUAL CONVENTION, CHICAGO, ILLINOIS, SEPTEMBER 24-27, 1940

▲ THE methods of controlling an open hearth furnace have changed considerably during the last five years. A few years ago, so many varying conditions seemed to be connected "inherently" with ordinary open hearth furnace operation that it was considered almost impossible to control them except through manual operations by the first helper. However, the demand for quality steel to meet rigid specifications has emphasized the importance of maintaining operating conditions within narrow limits in order to be able to meet the specifications. This has convinced the first helper that he requires tools—instruments, if you please—to measure accurately the various conditions which he wishes to control in order to maintain the narrower operating limits. The better control resulting has eliminated a great many of the so-called "inherent variables," which were so confusing. Consequently, the control of an open hearth furnace is now being reduced to the control of fundamentals. If these fundamentals are capable of being controlled by manual operations, guided by the information obtained by measuring instruments, the same set of conditions can be maintained by combined measuring and controlling instruments which are coördinated to control the same fundamentals.

Figure 1—Typical control panel for installation on a 150 ton basic open hearth furnace.

The control of an open hearth furnace may be considered under different headings, each consisting of several sub-headings. Any complete discussion of one group would, no doubt, include much information associated with the other groups. The following groups are suggested:

A. The open hearth furnace and system—the design, materials of construction, accessories, maintenance, and operation.
B. Labor—the melter, first helper, and operators.
C. The raw materials used to make the steel—the scrap, pig iron, flux, and additions.
D. The temperature and energy requirements to make the steel.
E. The finished heat—steel; a quality product.

A complete description of the many factors involved under a single group including diagrams, etc., becomes too involved for profitable discussion in this meeting; therefore, these remarks are confined to broad principles underlying the control of some quantities contributing to temperature and energy requirements included under group D.

It is often more difficult to measure accurately the changing conditions within the open hearth system which are to be controlled than it is to control the quantities contributing to change these conditions. This is true especially with temperature conditions and energy input. To overcome this difficulty, relative measurements may be used for control purposes where it is very difficult or not practical to measure the essential quantity. For example, it is desirable to have a continuous measurement of the temperature of the preheated air entering the furnace port for combustion and to follow the falling off in temperature during the interval between reversals. This may be accomplished with a specially designed, aspirating thermocouple; however, the life of the couple is rather limited, the maintenance is excessive, and the work is hot and difficult. In fact, with the available equipment, such a measurement is not practical and other temperature measurements taken in the regenerative systems are used as substitutes for the actual temperature of the preheated air. It has been found that the average temperature of the waste gases leaving the checker chambers, when measured with a protected, base metal thermocouple, or the temperatures of the checker brick

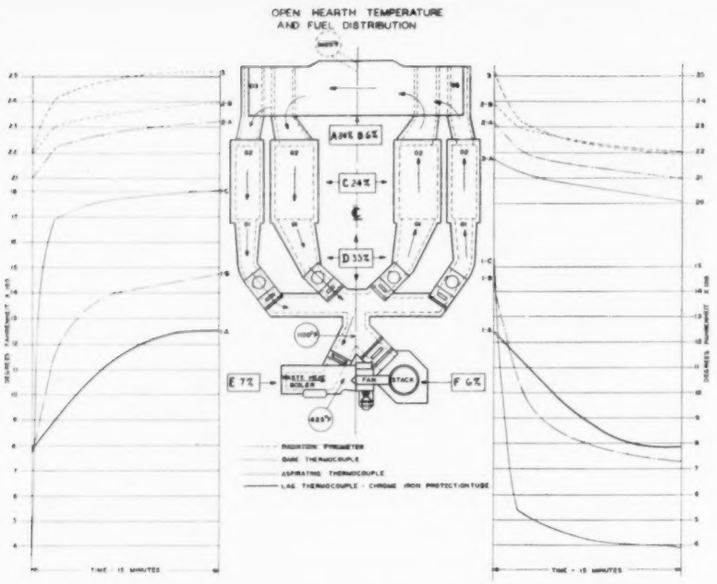


Figure 2—Diagram showing temperature distribution in an open hearth furnace.

at the hot end, when measured with a radiation pyrometer, do follow relatively the changing temperature conditions of the preheated air. Either of these measurements may be used for control purposes to maintain the temperature of the preheated air within practical limits. This relationship is shown on Figure 2.

Curves 1-A were taken with base metal thermocouples installed in chrome-iron protection tubes. Curves 3-A and 1-C were taken with aspirating thermocouples. Curves 2-B and 3 were taken with pyrometers sighted on the brick surfaces. The three sets of curves follow similar cycles but cover much different ranges in minimum and maximum temperatures. The locations where the temperature was measured are shown as positions O1, O2, and O3. The temperatures of the inside of the furnace roof and before and after the waste heat boiler are shown also on the slide. This gives a brief picture of the temperature conditions in the open hearth system.

The energy requirements necessary to maintain the temperature conditions in the open hearth system are indicated within the squares included on the diagram. The percentages in round figures are based on the total heat input, of which the burner fuel represents approximately 54 per cent. They were obtained by calculations based on values taken from heat balances of open hearth furnaces available in the literature, assuming a 150 ton, basic, open hearth furnace, producing a medium carbon steel, at a burner fuel input around 3,500,000 Btu. per ton. They are advanced with the thought in mind that they may promote discussion and may bring out facts which will show more definitely the utilization of burner fuel in the open hearth furnace. The figures are grouped under six headings:

A. To raise the temperature of the steel and slag to the tapping temperature—24 per cent
B. To promote chemical reactions—6 per cent
C. To preheat the combustion air—24 per cent
D. To take care of radiation and cooling water losses —33 per cent
E. To make steam in the waste heat boiler—7 per cent
F. Loss up the stack in the waste gases—6 per cent

These figures may vary considerably from values figured in relation to a particular furnace and practice.

Some factors which are connected with temperature conditions and fuel utilization are outlined briefly in the following.

REVERSING

The combustion air used in an open hearth furnace must be preheated in order to obtain a flame temperature high enough to melt scrap and to make steel. The preheat is obtained from the checker chambers in two stages: First, a part of the sensible heat from the outgoing waste gases is recovered and stored up in the checker brick; second, this stored up heat is used to preheat the incoming combustion air. In order to maintain the temperature of the preheated air within narrow limits the direction of travel of the waste gases and combustion air must be reversed at frequent intervals. This briefly covers the fundamental considerations connected with the regenerative systems and the reason for reversing. The reversing operation is being carried through manually or mechanically in different open hearth shops in different sequences.

A suggested sequence, outlined in consecutive steps, for a combined fuel (oil and gas) fired furnace, is as follows:

Step 1. Start the stack damper opening to permit the waste gas to be removed from the furnace quickly.

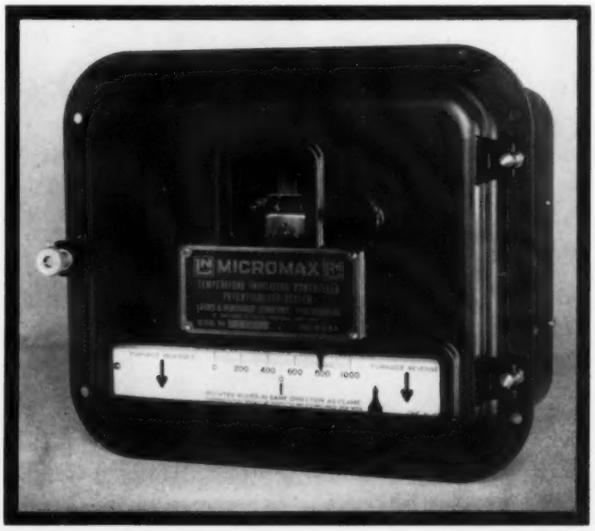


Figure 3—Potentiometer used to measure temperature difference and control reversal intervals.

Step 2. Turn off the oil (rapidly) and gas but leave on the atomizing steam to clean up the burner.

Step 3. Pause a few seconds to clear the waste gases from the outgoing checker chambers and fill them with combustion air. (This adds materially to the temperature of the preheated air used for combustion immediately upon reversing, and results in the furnace atmosphere clearing up quickly.)

Step 4. Reverse the atomizing steam to the oncoming burner. (This gives time for the steam at the burner to reach full pressure before the oil is turned on.)

Step 5. Reverse the dampers and air saucers.

Step 6. Turn on the gas to start the combustion.

Step 7. Turn on the oil (slowly).

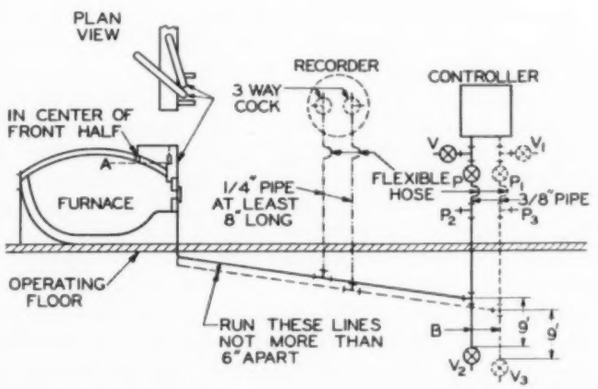
Step 8. Close the stack damper to maintain the desired furnace pressure conditions.

The reversing operation is listed in steps to emphasize the importance of making the reversing in a definite sequence. However, each step should follow immediately the completion or in some cases overlap the preceding step. It is possible to complete the reversing in approximately from 10 to 12 sec. It is desirable to carry through the reversing operation quickly in order to have the fuel on the furnace as continuously as possible to decrease the loss in temperature due to radiation while the fuel is off.

The time required to carry through the reversing operations varies over wide intervals in different open hearth shops. In some, the first helper carries through all steps at a common reversing stand; in other shops, it is necessary for him to make the complete reversing from two or more locations which require a much longer time. Under these conditions, the reversing can be made more quickly and more efficiently by mechanical means which can be actuated from one location.

Granted that the fundamental purpose of the checker systems is to recover a portion of the sensible heat from the waste gases and to return this heat to the furnace as preheat in the combustion air, and granted that the system has to be reversed at frequent intervals to hold the preheat within certain limits for efficient operation, it follows that the time interval between reversals should be determined by the temperature conditions within the checker systems themselves rather than be based on any arbitrary time interval.

Figure 4—Sketch showing plan of installation of furnace pressure recorder and controller.



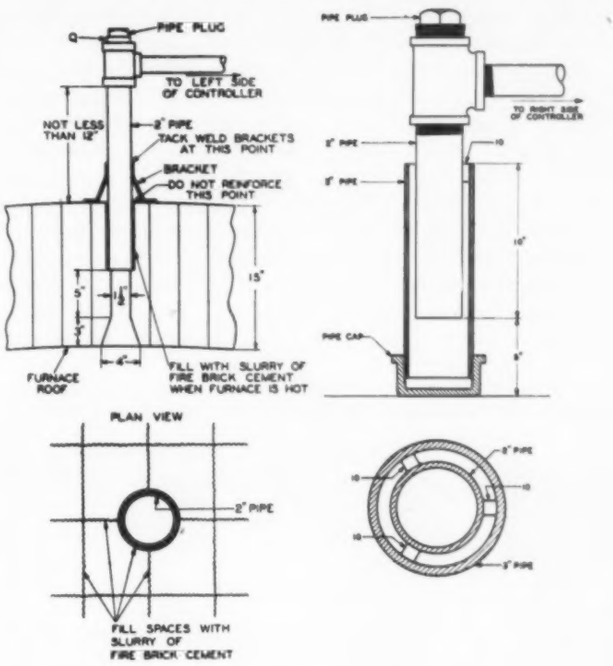


Figure 5—Sketch showing one method of installing pressure tap in the furnace roof.

The temperature-difference method for reversing the regenerative system is based on the difference in the temperature conditions within the heating up checkers (due to the outgoing waste gases), and the cooling down checkers (due to the ingoing combustion air). The temperature-difference can be set to hold the variation in the temperature of the combustion air within narrow limits and insures that the same temperature range is secured on both ends of the furnace. This method maintains the temperature conditions in the checker systems balanced and it will balance an unbalanced system by automatically changing the time interval between reversals in small increments, so as to increase the temperature in the cold end until it balances the temperature in the hot end. This insures the maximum temperature of preheated combustion air under the specific operating condition. When the system is balanced, the same temperature-difference may or may not require the reversals to be made at equal time intervals on the two ends of the furnace. It depends upon the amount of heat from the fuel and bath reactions carried along in the waste gases which vary the temperature conditions in the waste gas checkers. The temperature-difference principle for reversing may be arranged to give a signal for the first helper to carry through the reversing operations, or it may be used to initiate a reversing sequence which is carried through mechanically. The latter is used on the majority of the installations using this principle and is usually termed "automatic reversing."

The instrument used to measure the temperature-

difference and control the intervals between reversals, based on the setting of the desired temperature-difference, is shown on Figure 3. The instrument operates on the potentiometer principle and standardizes automatically the measuring circuit at set intervals. The thermocouples are connected opposed, so that the travel of the black index reverses in direction and keeps in step with the furnace operation. Thus it travels in the same direction as the flame or toward the heating up checker system. The signal is given or the reversal is initiated when this index reaches the arrow shown at the ends of the scale. The temperature-difference range (corresponding to the full travel of the black index) is shown on the top of the scale. The temperature-difference set on the controller is shown by the position of

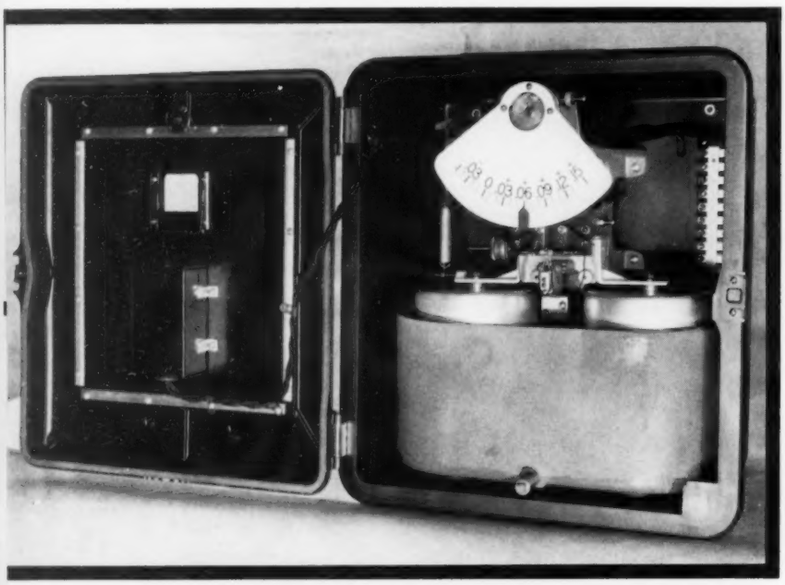


Figure 6—Pressure controller designed to operate on differential pressure between furnace and atmosphere.

the red index which is set by means of the knob shown above. The temperature-difference setting should be changed in accordance with the fuel input or for the various stages of the heat.

FURNACE PRESSURE

The pressure conditions within the open hearth furnace play an important part in the furnace operation, especially in the direction and location of the flame, the fuel economy, the temperature, heat distribution, the production, and the refractory repair and life. The pressure should be maintained slightly above atmospheric at the bath level, to prevent cold air from being drawn into the furnace around the doors and through other openings and cracks in the refractories. The range of pressure when measured in the middle of the front half of the roof is appreciably higher than at the bath level due to the stack effect in the furnace and usually falls between 0.05 and 0.085 in. H_2O. At pressures greater than 0.085 in. the "sting out" around the doors is pronounced with considerable wastage of heat and excessive damage to the furnace structure. The pressure conditions vary along the length of the furnace due to the fact that the fuel and combustion air enter the furnace under pressure while the waste gases are removed by a negative pressure or the suction of the waste heat boiler fan or stack. Since the pressure conditions are relative and vary with operating conditions, they should be measured and controlled from a location which represents corresponding relationships to both ends of the furnace. A tap installed in the center position of the front half of the furnace roof provides a convenient location and has proven satisfactory under operating conditions. This location can be seen from the floor in front of the furnace and any leakage around the tap quickly noted. A differential pressure balanced against atmosphereic pressure may be maintained at this location which will provide the relative pressures or balanced pressures desired at the wicket or bath level.

There are many details connected with installing the pressure tap and the pressure and atmospheric lines which play a large part in accurate pressure measurements; however, the principal points are shown in the following diagrams.

A plan view of a typical installation including the pressure recorder and controller is shown in Figure 4. It shows the relationship of the pressure and atmospheric lines, especially their parallel position and sloping to a low point below the controller. This provides for the drainage of any condensed moisture and its removal from the lines.

One method of installing the pressure tap in the furnace roof is shown in Figure 5. Please note that the tap is not fastened to the furnace tie rods but is supported by three legs or brackets resting on the furnace roof. This permits the tap to be carried up and down with the expansion and contraction of the roof without breaking the seal between the brickwork and the tap. Another point worth mentioning is the method of sealing the region around the tap with a fire brick slurry rather than with a thick mortar which causes a hot spot and injury to the furnace roof. Usually, if the slurry is added carefully to seal up all cracks around the tap before the furnace is lighted and again after the first heat when the roof has expanded and raised, no further maintenance is required during the roof life. The construction details of the inlet of the atmospheric line to eliminate the possibility of variations due to air currents are shown at the right.

The ability to measure accurately the small changes in the pressure conditions within the furnace makes it possible to control the pressure within the furnace by varying the negative pressure controlling the removal of the waste gases from the furnace. This can be accomplished by making suitable changes in the position of the stack or waste heat boiler damper which is used to throttle the negative pressure. The amount of the change in pressure within the furnace determines the amount of the change in the damper position to maintain the desired pressure condition. A small change in the fuel input may necessitate a small change in the damper position, while a vigorous bath boil may require

a quick, large movement of the damper to maintain the desired furnace pressure. In the case of a sudden bath "blow up" due to lime or ore, the rapid increase in furnace pressure is so great that the outgoing port becomes the bottle neck and the excess pressure blows out around the doors, etc., even if the stack damper were full open when it occurred. The stack damper movement, although rapid, cannot take care of this condition. These facts emphasize the importance of having different rates of movement of the controlling damper to meet the varying changes in pressure. It may be worth pointing out that the increase in the volume of waste gases which causes the increase in furnace pressure requires a few seconds to pass through the downtakes, slag pockets, fantails, checker chambers, and flues before passing the throttling damper, so that the damper movement should be correlated with the rate at which the waste gases are removed from the system. If the correct timing relation is not provided, incorrect movement of the controlling damper may even increase the varying pressure conditions within the furnace and result in an unstable or hunting condition. In view of the many factors involved, it is practically impossible for the first helper to make continuously the great number of adjustments required in the position of the controlling damper to maintain a set pressure condition within the furnace and he usually leaves the damper set at an average position and tolerates the resulting changes in furnace pressure.

A pressure controller designed to measure changes in differential pressure between the furnace and atmospheric pressure, and to regulate the movement of the throttling damper to maintain a stabilized set pressure condition regardless of the magnitude of the variations is shown in Figure 6. The furnace pressure enters under the left and the atmospheric pressure enters under the right bell. The differential pressure is weighed continuously by having this system balanced on a knife edge (the only moving part) resting in a V-notch in the support, similar to an assay balance. The pressure condition to be maintained is set on the scale and may be changed by a knob outside of the case. Immediately below the scale and moving with the balance arm are two sets of contacts. The front set close in response to pressure changes in the magnitude of around 0.001 in. of water. The closing of these contacts causes the throttling damper to be moved in steps of sufficient magnitude to correct the pressure change. The time interval between steps may be adjusted to equal the time required for the waste gases which have caused the change in pressure to be drawn from the furnace past the throttling damper before the damper makes another movement. A second set of contacts close in response to larger pressure variations and cause the damper to be moved continuously so long as they remain closed. As the pressure conditions return toward the set value these contacts open and the final adjustments to the damper are made in small follow-up steps initiated by the first set of contacts. The combination of these damper movements results in the damper being moved rapidly in a direction to oppose the pressure change for large variations and in small interrupted, follow-up

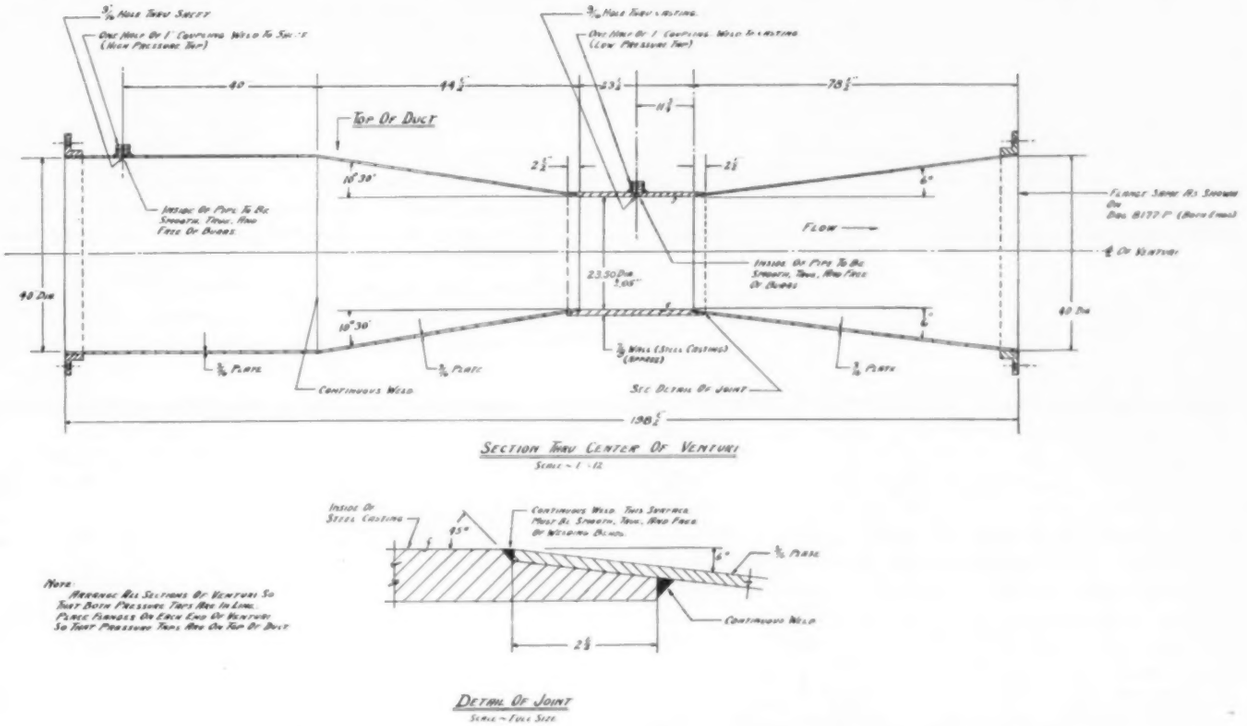


Figure 7—Details of construction of venturi throat for measuring air flow to open hearth furnace.

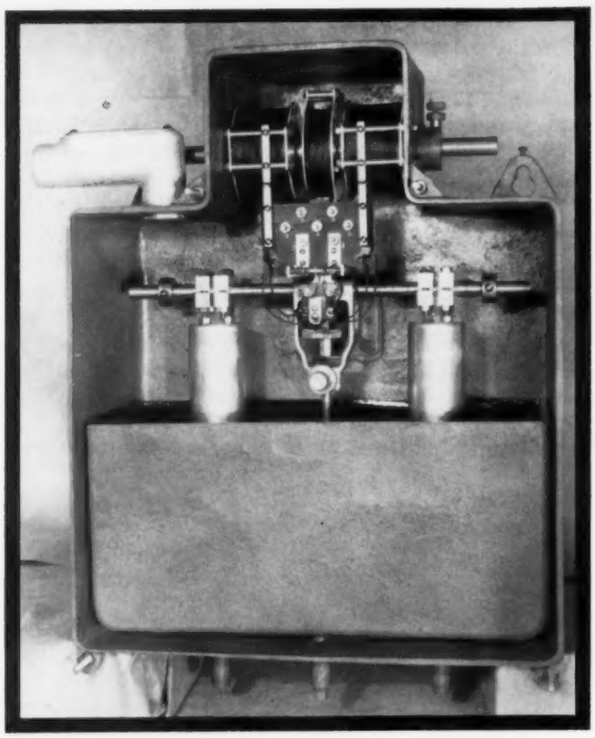


Figure 8—Operating on the weighing principle, this instrument controls volume of air or gas.

temperature of the fuel. In both cases an accurate measurement of the volumes being used is much more difficult to obtain than to control the volumes once the measurements are available.

The combustion air, on a natural draft type open hearth furnace, is drawn in through the air saucers by the "stack effect" which varies with the temperature of the checker chambers and the uptakes to the furnace port. The volume of air entering the furnace at a given checker temperature varies also with the condition of the checker openings or flues which fill up gradually with cinder carried along with the waste gases from the furnace. Combined with these conditions, the very small pressures available at the saucers make it practically impossible to measure the volume of air entering the furnace through the regenerative system. The first helper can vary within small limits the volume of air entering through the saucers by lowering or raising them. However, the degree of regulation is so small and so indefinite that he usually prefers to leave the air saucers set in one position and vary the fuel supply and the stack draft throttling damper, which controls the furnace pressure (and the amount of cold air being drawn into the furnace) to obtain the furnace and combustion conditions which he desires. The appearance of the flame and furnace atmosphere, as well as his experience on the furnace, become his measuring guide for the changes which he considers necessary. These methods of regulation or control vary greatly with the experience of the first helper and often result in an excessive fuel practice.

movements as the pressure approaches the set value. This prevents over-correction or too great a movement of the damper and thus eliminates hunting. The different rates of movement of the throttling damper to compensate for different magnitudes in the furnace pressure variations and the synchronizing of these movements in time intervals with the time required for the waste gases to pass from the furnace beyond the throttling damper results in stabilized pressure conditions within the furnace. One constant pressure setting is seldom maintained during a complete heat. Usually slightly different pressure conditions are best suited to meet the furnace operation during melting down, hot metal additions, the lime coming up, the working and finishing stages of the heat.

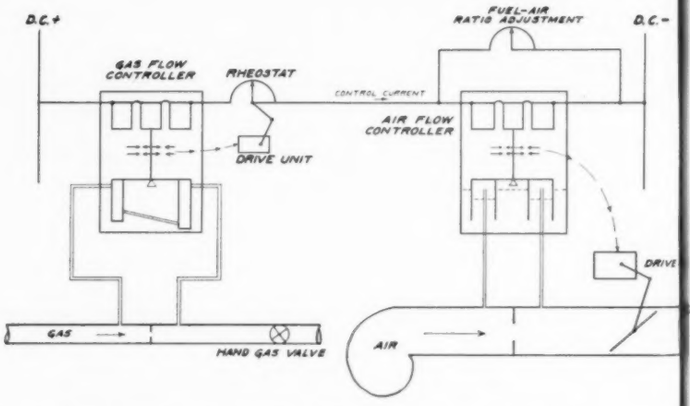


Figure 9—Schematic diagram showing the operation of gas-air diagram showing proportioning controls.

COMBUSTION

The rate at which the fuel is burned in the open hearth furnace depends upon the volume and temperature of the air supplied for combustion and the rate of mixing or contact of the fuel and the air in the combustion area. The proportion of fuel to air or the fuel-air ratio and the mixing rate determine to a large degree the temperature of the resulting flame and the temperature conditions mentioned previously. In order to control combustion conditions, therefore, it becomes necessary to measure and control the volume of the combustion air as well as its temperature, and also the volume and

The open hearth furnaces constructed during the last few years have provided for the measurement of the combustion air by employing forced draft fans. The fan delivers the air at static pressures sufficiently high (3 to 5 in. H_2O) in order that a drop of approximately 2 in. H_2O may be taken across a calibrated orifice plate or through a venturi throat for metering purposes. The air line leading from the fan to the checker chambers should be large enough so that the air velocity at maximum flow will be around 40 ft. per sec., and long

enough to provide for a straight run equal to at least 10 pipe diameters before, and 6 pipe diameters after the orifice plate, to insure straight line flow through this metering device. The venturi throat method for measuring the air does not require quite as long straight runs of line after the metering throat and the pressure recovery is considerably greater than obtained in the orifice method. This means that a lower static pressure at the fan outlet, to deliver the same volume of air, may be used in the venturi throat arrangement. There are other important details, such as tap locations, etc., which have to be taken into consideration in order to obtain an accurate measurement of the combustion air. Unfortunately, time does not permit a discussion of all the important details. It should be pointed out, however, that forced draft has provided a means of measuring the volume of the combustion air being supplied to the checker chambers at atmospheric or slightly higher pressures. It also provides a means of controlling and varying the volumes in accordance with the fuel requirements. These relationships hold only on furnaces designed and maintained to prevent air leaks.

The details of construction of a venturi throat installed in a forced draft line supplying combustion air to a 150 ton, basic, open hearth furnace is shown in Figure 7. We wish to call attention to the fact that the venturi throat and openings to the pressure taps should be smooth, true, and free from welding ridges. The measurement of the volume of gaseous fuels, such as by-product, blast furnace, and natural gas, may be accomplished by means of calibrated orifices or venturi

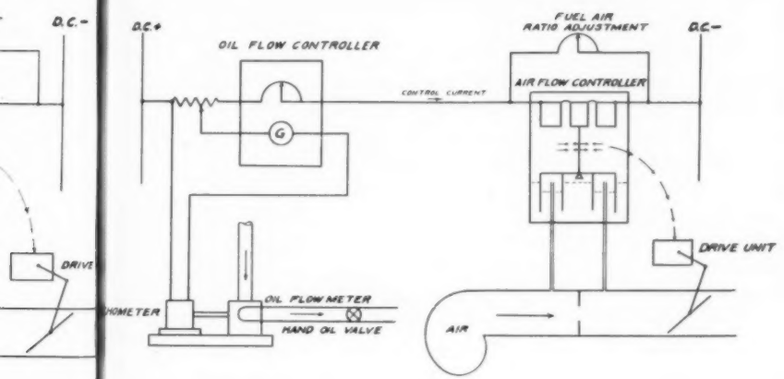


Figure 10—Diagram showing the operation of fuel-air proportioning control with oil firing.

throats. The fundamental requirements are much the same as those outlined under the combustion air. Liquid fuels (bunker C oil, tar, etc.) are usually measured by means of special orifice type meters or constant displacement type meters. The meter is generally calibrated to measure the fuel under operating conditions, especially the fuel pressure, temperature and viscosity. These conditions should be maintained as constant as possible. The steam used for atomizing the liquid fuel is usually measured, in the saturated condition, by means of an orifice plate, and then superheated before delivering to the burner.

Instruments are available now to measure, indicate, and record the instantaneous rates of flow of the combustion air, fuel, and atomizing steam, if they are installed correctly and operate under the conditions for which they have been calibrated. They may also be used for totalizing the fuel or Btu. input into the furnace. These measurements may be used for control purposes either by manual operations by the first helper or automatically by controlling instruments which are set by the first helper to maintain the set of conditions which he desires at any stage of the heat.

A controller which is used to control the volume of combustion air or the volume of the gaseous fuels is shown in Figure 8. It operates by the weighing principle, the same as the furnace pressure controller referred to previously, and provides for different rates of response to take care of changing demands in the operating conditions. The instrument measures the differential pressure across a calibrated orifice or venturi throat in the supply line by having the high pressure line enter under the left and the low pressure line enter under the right bell of the balance system. The differential pressure is weighed by the loading force or pull of the movable coil which moves with the balance system between the two stationary coils shown at the top. When this pull equals the differential pressure under the bells the controller is balanced, contacts open, and the control damper in the supply line remains stationary at the set volume. Any change in the volume which changes the differential pressure immediately upsets the balance of the controller, and closes the contact which causes the control damper to move to a new position, thus supplying the correct volume to balance the controller.

The operation of the controller is based on the fundamental considerations that the volume flowing through the calibrated orifice plate is proportional to the square of the differential pressure across the orifice plate and the pull on the movable coil is proportional to the square of the current flowing through the coils. The two square laws cancel and the volume flowing may be considered in terms of the current flowing through the coils. The current flowing may be measured accurately with an ammeter which may be calibrated in terms of volume of cubic feet, or in the case of gas in terms of Btu. or fuel input. Therefore, if the first helper wishes to change the volume being used, he simply turns a calibrated knob which changes a rheostat or resistance in the control circuit. This unbalances the controller which changes the volume flowing until the new differential pressure balances the new electric pull or loading force. This relation is maintained automatically until the first helper makes a subsequent change.

A first helper, who has been accustomed to operate an open hearth furnace by moving a hand control valve in the fuel supply line and to leave the combustion air saucers set at one position, usually prefers to duplicate this method of regulation even when using combustion control equipment. However, when forced draft is being used, he prefers to have the volume of the combustion air change each time that he makes a fuel change. The

control equipment may be arranged to function in a similar way.

A schematic diagram showing how the control equipment functions to meet these conditions is shown in Figure 9. The fuel (gas) and combustion air controllers, which have been calibrated for the theoretical proportions to give complete combustion, operate from differential pressures across the metering orifices as described above. The first helper opens or closes the gas valve in the line leading to the burners to obtain the amount of fuel he wishes to use to take care of the furnace conditions. The change in the volume of the fuel flowing through the orifice plate (installed in the fuel line) causes a change in the differential pressure which unbalances the fuel controller. The unbalance closes a contact which causes a motor operated rheostat to change the resistance in the control circuit until the current flowing through the coils supplies the correct pull on the movable coil to balance the controller and open the contact. The same current flows in series through the coils of the combustion air controller. The change in the pull on its movable coil closes a contact causing the motor operated damper in the air supply line to move until the differential pressure across the air orifice balances the new loading force. This opens the contact and the air damper remains stationary until the first helper makes another change in the fuel supply. The rheostat shown above the combustion air controller permits the first helper to increase or decrease the combustion air supply from the theoretical set ratio by a sufficient amount to produce a sharp or heavy flame condition to meet the particular requirements in the operating conditions. Thus the first helper has complete control over the volume of fuel being used at all times and, in addition, the combustion air changes at the same time with the fuel changes to maintain the combustion conditions which he sets.

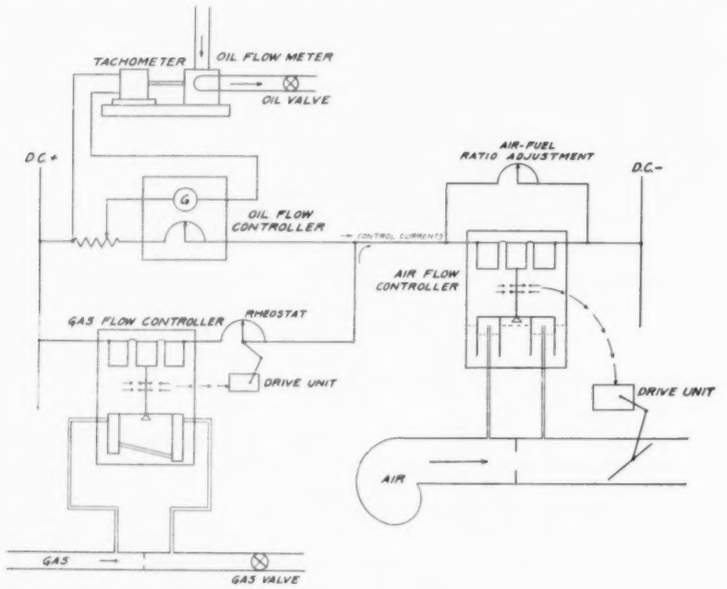


Figure 11—Diagram showing the operation of proportioning control with combination gas and oil firing.

The control equipment functions in a similar manner for the combustion control of bunker C oil as shown in Figure 10. The first helper sets the amount of oil he wishes to use on the furnace by positioning a vernier valve in the oil supply line leading to the burners. The volume of the oil is measured by a constant displacement type oil flow meter installed in the line. A d-c. tachometer or generator is connected directly to the oil flow meter and rotates with it. The tachometer generates a voltage which is directly proportional to its speed of rotation. This voltage is proportioned to the electric loading current by a potentiometer type oil controller actuating a motor driven rheostat. This current which represents the rate of oil flow, is passed through the coils of the combustion air controller and determines the rate of combustion air supplied in the same manner as described for the gas.

A schematic diagram showing how the control functions when both gas and oil are used at the same time on an open hearth furnace is shown in Figure 11. The first helper sets the volume of gas and also the volume of oil he wishes to use, and the combustion air will follow in the set proportion for all changes in the volumes of either fuel being used. Due to the fact that each fuel regulates its own portion of the total loading force on the combustion air controller, any number of separate fuels, each having its own controller, may be combined in this method of control which requires only one combustion air supply and control.

ROOF TEMPERATURE

This subject was discussed in considerable detail before a previous meeting of this Association and was published in the IRON AND STEEL ENGINEER.* At that time roof temperature was considered in the light of refractory saving or a means of increasing the roof life. The principle of operation depended upon reducing the fuel input to prevent the roof temperature from rising beyond a certain set limit. This was accomplished by using the temperature of the roof as a guide for the first helper to reduce the fuel input gradually to prevent the temperature from reaching the point where the brick surfaces began to sweat. In cases where the fuel was not reduced sufficiently by the first helper to prevent overheating, the controller was arranged to close an "on and off" valve which reduced the fuel a fixed percentage below what the first helper had set. This method has certain limitations and if used under certain conditions, the fuel was sometimes reduced by the instrument when the first helper needed higher temperatures to finish the heat regardless of the roof temperature or possible damage to the roof.

Roof temperature control has improved and changed in two important respects. First, the method of measuring the temperature of the roof. This is done by sighting through a suitable hole in the back wall upon the under side of the roof. Second, the method of using

*"Roof Temperature Control for Use on Open Hearth Furnaces," by M. J. Bradley, YEARBOOK, Association of Iron and Steel Engineers, 1935–36, pp. 188–194.

this temperature to control the fuel input. Instead of being used as a limit control, the roof temperature is now being used to regulate the fuel input to maintain the roof temperature at its safe maximum limit throughout all stages in the heat. This is accomplished by the temperature recording controller keeping the maximum fuel on the furnace at all times the temperature of the roof is below the control point, and reducing the fuel gradually to keep the temperature from rising beyond the control point. The fuel proportioning method, employing automatic droop compensation, is used. The

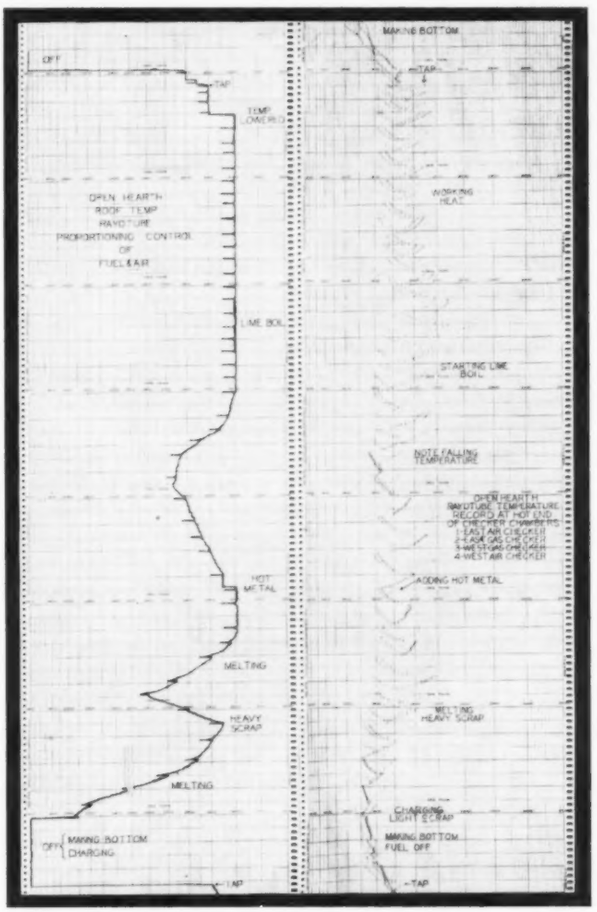


Figure 12—Temperature records of furnace roof and at bridge walls, with fuel input controlled from roof temperature.

roof temperature controller thus increases or decreases the fuel input to maintain the set temperature conditions. On furnaces equipped with automatic combustion control, the combustion air changes along with the fuel to maintain the set fuel-air ratio or combustion conditions.

The temperature record shown in Figure 12 is typical of a furnace roof where the fuel and air input is controlled by the roof temperature. It may not be necessary to discuss the control action for all stages of the heat but it may be worth pointing out that during all the time the temperature is below the control point (3000 degrees F.) maximum fuel (450 gallons of oil) is being supplied to the burners, and all the time the temperature is at the control point the fuel may or may not be at maximum. In fact, it is probably being turned down gradually in small increments to maintain the temperature at the control point. Usually the fuel input near the end of the heat has been reduced to approximately one-half the maximum amount used during the melting down stage. This method of control operates to maintain the roof at its maximum safe working temperature throughout the entire heat. It turns on the maximum fuel input immediately after the addition of hot metal when the temperature falls below the control point. This is the reverse of the usual practice under manual regulation, where the fuel is reduced before adding the hot metal and is seldom increased to maximum during the remainder of the heat. The latter practice tends to lengthen the time of the heat.

The temperatures measured on the bridge walls at the entrance to the checker chambers are shown in the record on the right. The measurements were taken with radiation pyrometers and show the heating and cooling cycles corresponding to the reversals. After the addition of the hot metal and during the time the lime is coming up, the heating up temperatures are shown to be considerably higher than average. This may be due to the increase in the heat resulting from the bath reactions.

A TYPICAL CONTROL INSTALLATION

Figure 1 shows a picture of a control panel (before shipment) now being used on a 150 ton, basic, open hearth furnace. The measuring, recording, indicating, and controlling instruments are all located at one position so that the first helper may see the measuring recorders and change the controls to obtain the condition that he may desire. The controls maintain the conditions which he sets until he makes subsequent changes. The furnace pressure controller and recorder are located at the left end of the panel. The temperature recorder and the temperature-difference controller for reversing are located in the next section. The combustion control instruments take up the remainder of the panel. They include a total Btu. input recorder, an oil flow recorder, a combustion air recorder, an atomizing steam recorder, a by-product gas recorder (not mounted), an oil flow controller, oil and steam pressure gauges and control knobs.

The method of combustion control provides for totalizing the combined fuel input to maintain a set Btu. input into the furnace. The amount of by-product gas to be used depends upon the available supply and is set separately by the first helper as well as the total Btu. input he desires. The oil is regulated automatically to hold the set Btu. input and if the gas supply falls off due to an increased demand in other sections of the plant, the oil flow will increase automatically to make up the Btu. loss due to the decrease in volume of by-product gas.

DISCUSSION

PRESENTED BY

E. C. McDONALD, *Combustion Engineer*, Republic Steel Corporation, Cleveland, Ohio.

J. M. BRASHEAR, *Open Hearth Combustion Engineer*, Inland Steel Company, East Chicago, Indiana.

VACLAV GREGOR, *Assistant Superintendent of Steel Producing Department*, Carnegie-Illinois Steel Corporation, Gary, Indiana.

M. J. BRADLEY, Market Extension Division, Leeds and Northrup Company, Philadelaphia, Pennsylvania.

E. C. McDONALD: Mr. Bradley has thoroughly covered the subject of control problems and has given excellent reasons for applying automatic features to open hearth furnaces. The system as outlined in his paper dealt with electric devices but I can state from experience with both electric and hydraulic controls that there is little difference in ultimate results and maintenance.

The first paragraph of the paper discussed measuring and controlling instruments. I presume controlling instruments are the automatic regulators, and measuring instruments refer to pyrometers, pressure gauges and flow meters installed as a guide for manual operation. I believe we are going to hear a great deal about the merits of the two classifications in future installations and the justification for installing the controlling instruments. My observations lead me to believe a large amount of the benefits claimed from automatic control can be attributed to the full line of measuring and temperature instruments that were installed with the control. This statement implies that it is going to be difficult for manufacturers of control to show justification for making the additional expenditure to automatically control all operations in order to improve upon a furnace well operated manually with a full line of instruments as a guide.

Mr. Bradley discussed automatic control under four groups, namely, reversing, furnace pressure, combustion, and roof temperature. In my opinion every open hearth should be equipped with automatic draft regulation and I believe this type of control has been accepted by the industry without reservations. The question of carrying the control program further is a matter of plant preference and justification. In order of importance I consider automatic reversal to rank after draft regulation, with combustion third and roof temperature fourth. My experience with both types of reversal leads me to believe temperature difference is more satisfactory than time for automatic reversing. Roof temperature control as now installed is handicapped by the method of taking temperature but when improved will become a valuable aid toward more efficient and economical furnace operation. When sighting through the backwall, flame instead of roof temperature is often recorded when burning large quantities of gaseous fuel along with oil.

The manufacturers of control have worked hard and I dare say without much profit to develop and service automatic regulation applicable to open hearth furnaces. The same can be said of the steel companies. However there is still plenty to be done to make an installation free of interruptions and entirely satisfactory to the operators. Finally and equally important is the training and adequacy of steel plant service personnel. If this matter is neglected, the whole control program is operating under a severe handicap.

J. M. BRASHEAR: There are one or two points covered in Mr. Bradley's paper on which a slightly different point of view may be of interest.

Since 1936 we have put in nine 150 ton furnaces at the north end of our No. 2 shop. All of these furnaces were equipped at the time they were built with instruments and controls covered in Mr. Bradley's paper, except automatic reversing. All furnaces were equipped with forced air fans.

This is considerably more equipment than has been installed, as yet, on our older 125 ton furnaces, only two of this group having forced air fans and instruments similar to the new furnaces.

A brief comparison of their operating performance is as follows for the year 1939:

Size of furnace	150 tons	125 tons
Average heat, gross tons	154	128
Time, tap to tap	13 hr. 23 min.	13 hr. 33 min.
Fuel consumption, gal. per gross ton	28.9	31.4
Gross tons per hr.	11.5	9.4
Average roof life, heats	416	407

It would be very difficult to determine what portion of the indicated reduction of fuel and increased production and furnace life can be attributed to the instruments and controls.

With reference to the value of the various phases of automatic control on the furnaces, we feel safe in saying that a saving of one to a gallon and a half of fuel per ton has resulted from better furnace pressure conditions. I think the next value can be placed on forced-air fans and the next on checker temperature equipment. I believe I would place the full-automatic fuel-air ratio control last.

With reference to the measurement of air flow, the long runs of pipe or ducting necessary in measuring air delivered from the fan, when using a calibrated orifice or venturi throat, are frequently hard to place due to lack of room in the older shops. I would like to know what Mr. Bradley's objections are to the use of booster nozzles of the venturi type or to the use of the calibrated orifice on the fan inlet. If we refer to the paper presented by Lionel S. Marks on "The Flow of Air in Fan Ducts" in Vol. 58, A.S.M.E. transactions for 1936, there is little to indicate any need for adhering rigidly to the discharge orifice or venturi throat.

Considerable expense and trouble can be avoided by the use of inlet measurements.

With reference to checker temperature measurement using radiation equipment, we have been experimenting with this type of measurement for over a year. Our initial experiment was conducted sighting against an extended section of the checker bridgewall, using a 9 in.

wall thickness. This seemed to give excellent results as long as the wall lasted, but unfortunately it burned down at 150 heats. Attempting to overcome this difficulty we constructed a wall of similar dimensions excepting the thickness was increased to 18 in. Our experiments with this wall thickness were very discouraging, showing that the wall failed to follow the temperature changes in the checker as closely as desired.

We are now sighting the unit out on the checker roof and have been obtaining excellent results to date. There seems to be a minimum of interference from smoke or dust particles and the temperature differential curve is much wider.

Of particular interest is the quick response in recording any excessive over-firing during hot metal, ore, or other additions. Also when the furnace is fuming badly from ore or scale charged heats, and it is almost impossible to determine the temperature within the furnace, the checker temperature recorder has been found to be of great value in determining the trend of temperature within the furnace proper.

VACLAV GREGOR: Mr. Bradley's admirable paper describes the change which took place in American open hearth steel plants in recent years in reference to the methods of controlling an open hearth furnace.

By controlling a furnace is meant to make the furnace work a certain way as far as combustion, draft, and furnace atmosphere are concerned. We thereby make it possible to produce steel of a quality satisfactory to the customer and to secure good results in furnace production, fuel practice, and rebuilding costs. These three items materially influence the financial balance of open hearth operation.

Before engaging in the discussion of the controls used in open hearth furnaces, we wish to express our ideas based on a heat balance of a modern 180 ton furnace operating on fuel oil and coke oven gas, 50 per cent hot metal charge, producing 17 tons of ingots per hr. with fuel practice of 3,500,000 Btu. per ton (22.5 gallons of oil per ton).

Heat balance of a 180 ton furnace—3,500,000 Btu. per ton:

Useful work: melting, chemical reactions, and heat in molten steel and slag	28.5 per cent
Heat losses: conductivity, radiation, cooling water losses, and cold air infiltration	29.5 per cent
Steam recovery in waste heat boiler	25.0 per cent
Stack loss	17.0 per cent
Grand total	100.0 per cent

Generally speaking, the commercial efficiency of an open hearth furnace is indicated by a high production of quality steel, per unit of time, along with a low fuel practice. Quality steel can be made only in a sharp working furnace. Low fuel practice is attained when the furnace losses are at the minimum. To accomplish the minimum losses in an open hearth system, it is necessary, first, to promote a high heat transfer in the combustion chamber, which condition permits a maintenance of comparatively low fuel input; second, it is imperative to reduce the conductivity, radiation, and infiltration losses to a minimum; and third, it must be possible to reproduce the results considered as satisfactory.

Principal factors affecting favorably the heat transfer in an open hearth furnace are:

1. High temperature and proper density of flame which presupposes a correct fuel air ratio and high air regeneration and a possibility to change the flame characteristics during the heat.
2. High roof permitting free flame development.
3. A certain degree of flame turbulance obtained by proper flame direction preventing the formation of an insulating layer of dead furnace atmosphere between the bath and the flame.
4. A certain minimum hearth area per ton of ingots which, for high hot metal charge, should be about 4.25 sq. ft. and for all cold charge about 6.00 sq. ft.

Principal factors which help to prevent heat losses of an open hearth furnace are:

1. Well sealed brickwork.
2. Insulated brickwork.
3. Tight doors and frames.
4. Certain balanced furnace atmospheric condition, reducing cold air infiltration.
5. Good flame direction reducing brickwork repairs.
6. Minimum of bottom and bank repairs.
7. Minimum of charging and tapping delays.

Considering the large number and complex nature of important factors to be observed in the operation of an open hearth furnace, it is obvious that this task can be successfully met only if the furnaceman has at his command necessary control instruments, which in all instances measure and register:

Fuel input
Fuel temperature and pressure
Atomizing steam pressure and temperature
Air input and temperature
Furnace pressure and flue draft
Roof temperature
Reversing interval

The actual controlling, based on the measurements, is done either by hand, or by an automatic control.

In the open hearth department at Gary there are 52 furnaces, details of which are as follows:

Fifty-two furnaces are equipped with measured fuel input, both oil and coke oven gas.

Thirty-four furnaces have measured forced air hand controlled.

One furnace has measured forced air, automatically controlled.

Seventeen furnaces have natural draft type air supply.

Seven furnaces have automatic full floating temperature roof control.

Thirty-five furnaces have automatic furnace pressure control.

Seventeen furnaces have hand furnace pressure control.

Fifty-two furnaces have 6 point registering pyrometers for hand control of checker temperatures and flue temperatures and for hand control of furnace reversals.

The controlling gauges and apparatus are assembled on an instrument board, in a practical arrangement, designed for the convenience of the furnaceman. We maintain a staff of competent fuel engineers who daily

(*Please turn to page 50*)

Developments in

BLAST FURNACE GAS CLEANING

By C. H. Glaser

Superintendent of Blast Furnaces

CARNEGIE-ILLINOIS STEEL CORPORATION

YOUNGSTOWN, OHIO

Presented before A. I. S. E. ANNUAL CONVENTION, CHICAGO, ILLINOIS, SEPTEMBER 24-27, 1940

▲ THE two primary objects of this paper are (1) to trace the developments in blast furnace gas cleaning, and (2) to describe some of the later processes and types of equipment.

During recent years, the problem of gas washing has been growing in importance, due on the one hand to a tendency to produce more dust from finer ores, larger furnaces, and harder driving; and on the other hand to an increasing recognition of blast furnace gas as a desirable fuel, plus the desire to save flue dust as a conservation measure. A great amount of flue dust was wasted in early years, but the advent of the sintering plant made it possible to recover this dust. This required a more efficient gas cleaning system.

As labor costs have been brought down to a point where they cannot be much further reduced, fuel conservation becomes increasingly important as the next step toward further economies in the production of pig iron.

Fine-cleaned gas for hot blast stove use brought out the substantial fuel savings possible through the use of small checkers. By better utilization of the brick-work in heat transfer, and with no slag formation to insulate the heating surface, it is now possible to supply more blast heat with three stoves than was formerly possible with four.

The fuel value of blast furnace gas runs into large figures, a 1000 ton furnace producing daily the gas equivalent of about 400 tons of coal. A saving of even a few per cent of this fuel is a worthwhile economy, and there are probably few plants where such an economy could not be effected. This economy, coupled with the desirability of a sulphur-free gas for metallurgical purposes, should encourage steel plant operators to give their closest attention to the utilization of blast furnace gas for purposes of steel heating and melting.

Much has already been accomplished along these lines. We find blast furnace gas in use in stoves and boilers, for underfiring coke ovens, in soaking pits, open hearth furnaces, and various heating furnaces. Every cubic foot of gas saved at the stoves makes available that much more gas for other uses.

Additional impetus has been given to the use of blast furnace gas by the decreasing cost of cleaning. Where five to six cents per ton of iron was considered as an average cost for primary cleaning ten years ago, with about .2 grains of solids per cu. ft. of gas, today it is possible to maintain dust contents as low as .008 grains per cu. ft. for approximately the same or less cost.

The first step in making possible the broader applications and economies of blast furnace gas is to get clean gas.

TYPES OF EQUIPMENT

Although there is quite a variety of equipment used for producing clean gas, these facilities may all be classified into a few main groups, as follows:

A. Dust catchers
B. Primary washers
   1. Dry gas washers
   2. Wet washers
   3. Moisture eliminators
C. Secondary washers
   1. Theisen
   2. Disintegrators—rotary and stationary
   3. Electric precipitators
D. Flue dust recovery
   1. Sumps
   2. Dorr thickeners

Practically all furnaces today are equipped with one or more dust catchers. All of them are based on one of three basic principles, or various combinations of them, namely:

1. Changing direction of gas
2. Reducing velocity
3. Centrifugal force

A good dust catcher should remove about 60 to 70 per cent of the dust. For further removal of dust from gas, some form of primary washer is used.

The dry gas cleaner was developed to clean gas and still retain the sensible heat of the gas. Cleaning was done with filters without the use of any water. Low cost of operation was the chief advantage, but this was more than offset by operating difficulties and the fact that the loss in thermal efficiency due to retained water vapor was greater than the heat gained by conserving the sensible heat of the gas. This, coupled with the demand for a cleaner gas than a dry cleaner could produce and the greater possibilities of the wet washer in this direction gradually eliminated the dry cleaner.

A wet washer, delivering saturated gas under 90 degrees F. will give a gas with more available Btu. per lb. than the dry cleaner. When the saturated gas temperature goes higher, say over 110 degrees F., the moisture content rises to such an extent as to decrease the available Btu. per lb. down to, or even below, that of the dry cleaned gas. Somewhere along this temperature range a break-even point exists, so far as available heat is concerned, and, should an efficient dry cleaner be developed, perhaps in combination with a precipitator, it might be worthwhile to consider such an installation at localities with a limited water supply or with only high temperature water available.

The first wet washer units tried to clean gas by impinging it upon the surface of water or by passing the gas through a series of sprays, perhaps with baffles here and there to direct the flow of gas and to help break up the water into a finer spray, in the hope that the drops of water would strike the dust particles, thus giving them enough weight to drop out of the gas.

This method seemed, however, to be limited to reducing the dust content to about .3 grains per cu. ft. The remaining dust in the gas was so fine that it could remain floating in the gas for long periods of time. When a drop of water approached such a fine dust particle, it would necessarily cause a slight compression of the gas in the direction of motion. This forced the gas with its fine suspended dust off to one side, allowing the water drop to pass on its course without coming in contact with the fine dust particles.

The .3 grain gas started the trend towards small checker stoves by making it possible to decrease checker size from 9 in. x 9 in. to 6 in. x 6 in., giving more available heat without additional expense for cleaning checkers and, at the same time, more available gas for other purposes.

The advent of the gas engine followed closely the development of the wet primary washer, and the next logical step was to develop a secondary washer to provide gas clean enough for engine use. The Theisen washer was the answer to this, and while Theisen cleaned gas was too expensive for stove use, it was found economical in combination with the savings effected by gas engine operation. There are quite a few of these units still in use, cleaning gas down to .003 grains per cu. ft.

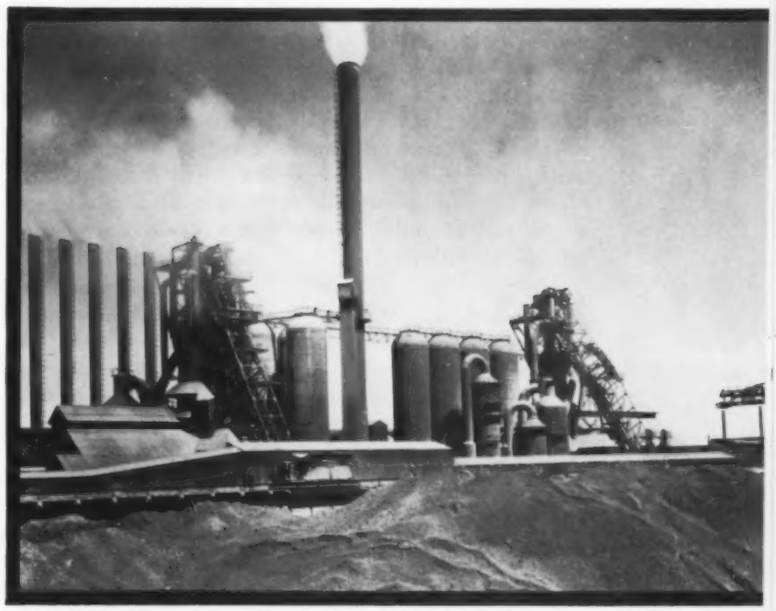
A later theory contended that wet washing removes the fine dust by condensing water drops on it, rather than trying to strike the dust particle with water drops. This idea is based on the assertion that rain drops are formed by moisture condensing on the surface of microscopically small dust particles in the air.

The usual procedure in this type of cleaning is to rough wash the gas with hot water at about 150 to 160 degrees F. The hot gas on entering this hot stage will evaporate a portion of the hot water and carry it along; the hotter the water, the more that is evaporated and carried up to the cooling or condensing stage.

There the hot wet gas is passed through sprays of cold water, which cool the gas down to the desired temperature, condensing the water vapor down to a moisture content in the gas equivalent to saturation at the lower temperature. It is this condensing stage which is relied upon to form water drops on the fine dust particles and give them enough mass to drop out in the washer, or make it possible for them to be removed in a water eliminator.

This theory is utilized in the Feld washer, in which mechanical means are used to form the water into a mist; cold condensing water from the top is drawn off at the third or fourth stage, leaving hot water for evaporation in the bottom stages.

This washer consists essentially of a series of sections, usually seven, arranged vertically one over the other. Gas enters at the bottom, and passing through each chamber or section, leaves at the top. Water flows



The blast furnace, with its great volume of dirty gas, prevents a gas-cleaning problem which is met in a variety of ways.

from top to bottom, from section to section, with about half of the water being drawn off at the third stage before it reaches the evaporation stage, so that a temperature of 150 degrees F. can be obtained in the water at the bottom. Each section is provided with a cone rotating about a vertical shaft in a pan of water, all cones being fixed to one shaft which is driven by a 150 hp. motor on top. Water is raised through the cones by centrifugal force and atomized at the upper edge. Each cone is so constructed as to form a series of

cascades composed of fine drops of water through which the gas must pass.

Most of the washing is done in the bottom three stages, the function of the upper part of the washer being to cool the gas sufficiently to condense water on the fine dust.

There were many installations of this type of washer, and experience indicates that it is possible to get a gas cleanliness of about .12 grains per cu. ft. This allows in turn the use of 4 in. x 4 in. stove checkers instead of the 6 in. x 6 in. spacing formerly used. Thus another step toward economy and making more gas available for other uses was made.

The disintegrator came into use shortly after the Feld washer and was found to be a great help to those operators who had increased the size of their furnaces but still had good stoves with a relatively small total heating surface. The .01 grain or less disintegrator gas permitted fillers to be installed in the stoves to provide the increased heating surface so sorely needed. The disintegrators, however, had the same disadvantage as the old Theisen washer, namely, they used too much power.

The electric precipitator is, for the present, the final answer to low cost secondary cleaning. Precipitators had already been in use for some years for cleaning air and various gases in other industries and for cleaning dry hot blast furnace gas at Pueblo, Colorado, and Birmingham, Alabama, when in 1931 the first full size unit was installed at the Campbell plant of Youngstown Sheet and Tube Company, where wet primary gas was used. The results obtained from this installation led others to install them and one of these later installations, which was a combination of tower washer and electric precipitator, did so well as to stimulate further experiments.

New designs, combining the existing Feld type washer and some type of condenser and eliminator, were developed which could be adapted to existing installations of the so-called mechanical washers. The price of installation and cost of operation of these new units compared favorably with tower and precipitator combinations. There are quite a few of these adapted installations that are giving a gas with a dust content of about .05 grains per cu. ft., which is considered clean enough for 3 in. x 3 in. stove checkers and most other applications.

The electric precipitator is interesting in that it embodies features so different from those of the ordinary wet washer which cleaned by:

Impinging on a wetted surface or water
Centrifugal action
Change in velocity and direction
Filtering and washing in fine sprays
Cooling and condensing

The precipitator depends upon ionization of the gas to do its work and the electric wind effect of a discharging point.

Let us consider a brass sphere mounted on an insulator. It is capable of holding an electric charge and the charge will be evenly distributed over its surface. However, if a point is fastened to the sphere, we find that it will no longer hold a charge, and that, if the point is held near the flame of a lighted candle, the flame will be deflected. This effect, due to the high concentration of electricity on the tip, is called electric wind, and is caused by ionization of the air.

This wind effect is utilized in the electric precipitator for cleaning blast furnace gas. The field is produced in tubes 8⅝ in. in diameter, 15 ft. long. A ¼ in. square twisted rod through the center of each tube serves as the negative electrode, and the tube as the positive. Water is allowed to run uniformly down the walls of the tubes to remove deposited dust.

A dust particle entering a tube can do one of three things:

It can touch the walls of the tube and be washed away.

It can touch the center electrode and get a negative charge of electricity which will be repelled by the electrode and attracted by the walls of the tube. The dust will reach the wet walls and be washed away.

It can come straight up between the electrode and walls, not touching either. In this case, the electric wind will force the particle over against the wet walls.

The important points in electric precipitator installations are to have high enough voltage, and to have the gas moving slowly enough to give the dust time to reach the walls of the tube before passing through.

Another type of cleaner that is new on the market is interesting, although it embodies no new principles. This is the stationary disintegrator, which is composed essentially of three parts: the spray nozzle or jet, a venturi throat or velocity chamber, and a concave disc called the deflector cap. Water passes from the spray through the venturi throat against the adjustable deflector cap at 150 lb. per sq. in. pressure.

The stationary disintegrator is intended for use in conjunction with various types of washers and is adaptable to the redesign of old equipment.

Another interesting unit, seemingly very flexible in application, is a form of impingement baffle plate. This is said to remove both fog and mist particles as well as solids. It consists of a perforated plate, placed horizontally, which divides the gas stream into a large number of jets. Each jet impinges directly upon an individual impact baffle surface overlying each perforation at approximately the vena-contractor of the jet. The wash unit works on the impact principle, the dust merging with the water on the plates upon impact. Movement of the gas through the water overlying the perforated plates causes a turbulent action which prevents the jets from closing up. Some water is carried up with the gas and is removed in a water eliminator.

Perhaps most illustrative of modern water eliminators is the cyclone type. This consists of about a dozen rubber covered vertical plates curved 180 degrees, and depends upon centrifugal force to throw the water against the walls. The rubber coating serves to keep the walls free and open and facilitates cleaning.

SUMMARY

We have thus gone through a period, or rather three periods of evolution in gas cleaning, starting over half a century ago with the introduction of the dust-catcher, followed some 20 years later by the primary washer, both dry and wet, giving gas with a dust content of .3

to .5 grains; in the same period, the Theisen washer with high cost secondary gas of .003 grains was introduced. This in turn, about 20 years later, was followed by our present-day equipment, giving primary gas of .05 to .15 grains and low cost secondary gas of .008 grains or less.

The initial cost, equipment on hand, cleanliness required, dust disposal, cost of operation, are all variable and important factors which require careful and separate consideration for each locality.

The outstanding criterion, perhaps, is the required cleanliness. It must be determined with an eye to the future, keeping in mind that overcleaning of gas is almost as bad as insufficient cleaning, as it represents expense without commensurate savings.

At present, the prevailing opinion appears to be that secondary cleaning is not so important or necessary as at first believed, and that a primary clean gas of .03 to .05 grains is adequate for use in 3 in. x 3 in. stove checkers during a campaign.

The object of cleaning blast furnace gas is two-fold: to remove dust from the gas, and to remove moisture. Too little emphasis has been placed upon moisture, which decreases the maximum possible flame temperature and causes trouble in mains, burners and valves. At some plants this condition gets so bad as to freeze up the burners in the winter.

It would be well to include this item of moisture control for consideration when selecting equipment.

Flexibility is another important item, especially for secondary washers. As far as possible equipment should be arranged so that breakdowns will not cause interruptions in furnace operations.

There is no single gas washing system or type of equipment which fits the needs of every plant, and the large number of different washers in use today may be taken as a sign of progress. Present-day efforts are toward developing the best practice to fit local conditions.

DISCUSSION

PRESENTED BY

GORDON FOX, *Vice President*, Freyn Engineering Company, Chicago, Illinois.

GORDON FOX: Mr. Glaser has given us a comprehensive picture of the entire field of blast furnace gas cleaning. Although this problem has been before us for years, it does not appear that present solutions have reached the stage of finality. Evolution is still in progress. This is another one of those frontiers which are gradually moving back.

The wet cyclone cleaner, as a secondary stage following a primary or scalping cleaning, is a relatively recent addition in the realm of gas cleaning in that it has seen but a few years of commercial service. Its specific performance depends somewhat on local conditions. Broadly speaking, however, it removes 30 to 50 per cent of the dust remaining in primary-washed gas. It also removes the entrained moisture in the gas effectively. Mr. Glaser has stated that this is an important part of the task.

Experience with the cyclone cleaner indicated improved efficiency when the entering gas contained plenty of moisture. Fine sprays introduced into the gas stream ahead of the cyclone were somewhat helpful. It appears to be rather obvious that some fine dust and fume particles are not wetted either in the primary washing stage or in a fine spray. These fine dry particles are able, in some degree, to pass through the cyclone without being caught. In view of their extremely light weight in dry condition, centrifugal action does not remove all of them. In view of this fact, the employment of a fog in the region preceding the cyclone was considered to be logical. This fog is created by condensation brought about by reduction of the temperature below the dew-point of the gas. It is the function of this fog to moisten the fine, light dust particles which cannot be captured by sprays or by contact with wetted surfaces. Condensation of a slight amount of moisture, enough to dampen such particles, adds to their weight and renders them more susceptible to removal by centrifugal means in a cyclone.

An experimental gas cleaner was constructed as a pilot plant to test this idea. A large number of tests were run over a sufficiently wide range of conditions to indicate the nature and degree of influence of the governing factors. These tests threw considerable light on the operation of creating such a fog and also proved that a substantially increased degree of secondary removal can be accomplished if this effect is incorporated as a step preparatory to the wet cyclone.

Mr. Glaser has at his plant an installation which incorporates this principle. Local conditions placed some substantial limitations on this installation. Nevertheless, the results thus far attained are encouraging. They appear to substantiate, in general, the results previously obtained on an experimental scale. It may be proper to intimate that, even were local conditions more favorable, it should hardly be expected that the initial commercial installation would immediately show the superlative in performance which may be possible to the general method employed. Already some steps are in progress looking toward improvement.

The disintegrator was mentioned. While this is by no means a new device, there is some indication that its merits have not heretofore been fully realized in this country. In Europe it has found very wide acceptance. In simplicity, reliability and availability, it is unsurpassed. It handles short-time overloads, such as furnace slips, admirably. It involves a minimum in pressure drop and can readily be designed to incorporate a moderate boost in pressure. Its water requirement is low. It is compact, accessible and easily serviced. It is low in first cost. Its one and only disadvantage is in the matter of power consumption. It should not be taken for granted that this is necessarily excessive. Local conditions alter figures. It may be broadly stated, however, that where electric power costs about 4 mills per kwh., or steam costs about 20 cents per thousand lb., the overall cost of disintegrator operation may be quite in line with other gas cleaning methods. The

downward trend in the cost of electric power and steam are factors favorable to the disintegrator.

The impression seems to be rather widespread that the disintegrator is suited only to very fine gas cleaning, *i. e.*, to deliver gas containing 0.01 grains of dust per cu. ft. or less. This is not entirely true. By variation of the number and disposition of bars and by varying the water usage, the cleanliness may be varied over a considerable range, from gas of 0.02 grain category to the finest cleaned gas of 0.005 grains and less. The power consumption is higher, the more thorough the cleaning; or conversely, the power consumption may be materially reduced if the highest degree of cleaning is not required.

Bradley DISCUSSION

(*Continued from page 45*)

inspect each unit and check its accuracy. They see to it that the controls are used properly, and provide for the maintenance. We believe that the installation of controlling apparatus is indispensable for commercial operation of open hearth furnaces.

M. J. BRADLEY: Mr. McDonald has mentioned the difficulty of flame temperature interfering with roof temperature measurements and control. This difficulty may be eliminated on practically all installations by careful installation of the rayotube. It should be installed so that it sights on the roof directly over the tapping hole and very close to the skew back. In fact, the nearer it is sighted to the back wall the better. It has been found that when sighted within 6 or 8 in. from the back wall the influence of flame variations is entirely eliminated. Roof temperature control is relatively new and when more information is available on this method of control it may be used much more extensively. There are at present somewhere around 150 installations on open hearth furnaces.

Mr. McDonald has mentioned the importance of intelligent supervision and maintenance of the control instruments and equipments. This subject has been discussed so frequently that no specific mention of it was made in the paper. However, it is one of the most important considerations connected with open hearth control. The control instruments are expensive and require a certain amount of checking and maintenance attention in order that they may function correctly if they are to prove a worthwhile investment.

Mr. Brashear wishes to know the objections to the use of booster nozzles of the venturi type or the use of the calibrated orifice on the fan inlet. It was not the intention to raise objections to these methods of measuring combustion air but rather to limit the discussion to the methods of measuring used generally on open hearth installations. Mr. Brashear has pointed out the principle objection to the use of the duct orifice or duct venturi method, namely, the increased length of straight run of duct required for accurate measurement. However, where space is available, the increased length of duct adds very little to the initial cost and the overall cost and simplicity of installation favor the duct methods.

The measurement of the air, although very important, should be considered in relation to control functions. The large volume of air between the fan and the throttling damper after the metering device has a decided stabilizing effect on the air controller. The differential drop across the orifice plate or venturi metering throat may be calibrated to use available recorders and at the same time furnish sufficient power for control purposes. The measurements are made under conditions which are relatively constant and should duplicate under like conditions. Usually the fan will deliver approximately 50 per cent more air for combustion than that required for the maximum fuel used so that the metering orifice or venturi are being used within their optimum range.

Mr. Gregor has contributed much valuable information on open hearth operation and control. Fortunately, he has available 52 furnaces on which to carry out his investigations and check his results. He has mentioned the importance of combustion control or the correct fuel-air ratio and high air regeneration as a means of controlling flame characteristics and temperature. I am sure we all appreciate his valuable contribution and many additional facts connected with the subject under discussion.

In conclusion, kindly permit me to repeat that it is very difficult to control a quantity unless it may be measured accurately. It is also impossible to control automatically any quantity or condition which cannot be controlled by manual regulation.

Water Requirements of Steel Plants

By L. N. McDonald, Jr.

Fuel and Power Engineer

CARNEGIE-ILLINOIS STEEL CORP.

YOUNGSTOWN, OHIO

This paper, with the three immediately following, form a symposium on steel plant water supply presented before the A.I.S.E. Pittsburgh District Section, January 13, 1941.

▲ THIS discussion is intended to give a general picture of the services, quantities, and qualities of water requirements for a typical steel plant. This subject, which covers a large and diversified field wherein conditions and requirements vary greatly with locality and product, has certain characteristics common to nearly all steel plants. These characteristics will be discussed together with a few general schemes which are typical of many plants in the steel-making industry.

The hypothetical steel plant which we shall consider is a complete integrated group capable of all operations from ore reduction to finishing of various steel products with the exception of a few processes such as coke production. It will be situated in the northern industrial region along a rather small stream. It will have blast furnaces, open hearths, bessemers, blooming and slabbing mills, a diversified set of finishing mills from the old type hand mills to modern strip mills, and will be fed from a central steam and power generating station. All newer type mills would be electric driven with the older type mills gradually being changed over from steam driven to electric driven. The plant would have an annual capacity of 2,000,000 net tons of ingots, or 1,400,000 net tons of finished steel. The total day turn force would be approximately 3500 men including all office and supervisory personnel. The plant site would cover approximately one-half square mile and would be located on an "industrial" river which would be polluted to a high degree by wastes from many other industrial plants located upstream.

SOURCES OF WATER

It is obvious that the water requirements of a steel plant of this nature are sizable. For supplying this large demand practically all sources provided by nature can be and are used. These sources vary from the "industrial" river water, which carries much suspended matter, to natural and artificial lakes, wells, and subterranean streams. The sources may be controlled by the steel company or by outside interests.

The sources must furnish an adequate and unfailing supply. Otherwise storage, recirculation, artificial cooling, and special preparation and treatment become necessary.

The unit cost of each source varies with local conditions. Because the degree of clarity and purity necessary for the various services covers a considerable range, two or more sources are frequently used. The choice of sources of any given character then becomes a question of dependability and economy. Rivers have been made more dependable sources by the construction of artificial flood reservoirs in feeder streams which tend to stabilize water flow by reducing the spread between maximum and mimimum river level. Local conditions usually determine the economies of the various sources. In general, surface waters are high in suspended matter and fairly low in total minerals, while springs, wells, and all other deep subterranean waters are clear but high in objectionable minerals.

Dependability is very important. Even partial failure of the water supply will cause very costly slow-downs in operations, increases in defects and rejections of product, and increased repair and maintenance requirements on machinery and equipment. Because provision for reserve capacity of steel mill units is becoming ever more costly, specifications on water needs should be maintained closely to assure against emergency outages, especially of boilers and power generating equipment.

Low rate cooling, with a temperature rise of 5 to 15 degrees F., accounts for about 83 per cent of the total water requirements. About half of this 83 per cent is used for indirect contact cooling, such as circulation through coils and jackets, and the other half for direct contact cooling through the use of sprays or baths. Another 14 per cent is used for various services such as washing and wetting, pressure services, sluicing, processing, etc. For this total of about 97 per cent a fairly soft water, low in acids, harmful minerals, and total solids is satisfactory.

Nearly all river waters can be brought into this classification with a moderate amount of treatment. Where rivers or lakes are not available, this water must be supplied from deep wells or other subterranean sources. Such water may require extensive preparation and treatment and will necessitate special care in its economical re-use.

The remaining 3 per cent, although comparatively small in volume, requires greater consideration because

of its more exacting requirements and the higher unit cost. This cost may run as high as 10 to 15 times that of general service water. Some processing and spray cooling water may require either special treatment or a special source to avoid surface defects on finished product, *e. g.* pickling baths, scrubbers, etc. Another portion may require treatment or a more suitable source due to its high temperature rise with the resultant corrosion and sedimentation which can be expected if the river water is used, for example, for gas engine cooling.

Another portion is required for feedwater make-up. As full feedwater treatment has become an art in itself, it is common practice at present to send supply and boiler water samples to outside laboratories which specialize in prescribing water treatments. The fact is generally accepted that modern boilers, with their high pressures and temperatures, extensive heating surfaces, and high steaming rates, require fully treated feedwater for safety and economy.

Lastly, there are the welfare and drinking water services which, as we know, must be safe and pure for human consumption and use. Here it is frequently necessary to choose between the use of deep wells or the purchase of water from a public utility corporation.

GENERAL CONSIDERATIONS

Most plants were originally located on streams with sufficient minimum flow to meet requirements. However, plant expansion and increased water services have caused shortages, both localized and general. This can be met in the district by recirculation or by artificial lakes and for the individual plant by constructing a small dam in the river below the intake and disposing of part of the waste water above the dam for recirculation.

The major portion of plant water supplies need be raised to relatively low heads; every additional unit of unnecessary lift represents a sizable increase in the cost of this water. Therefore, a plant located at just sufficient height to be above maximum flood stage is able to keep the required lift to yard level at a minimum and realize a corresponding advantage in pumping. Some idea of the magnitude of the pumping job is given by the fact that the weight of the average water requirements is approximately 150 times the weight of finished steel production of the plant.

The plant's pumping station intake requires special consideration and protection against floating debris and large suspended matter by the use of floating booms, trash racks, screens, and strainers as required.

The water distribution system requires many miles of pipe lines and conduits from 48 in., and even larger, down to 2 in. or smaller. These lines, which are carried underground wherever possible to prevent freezing, were previously made of many materials such as brick, concrete, cast iron, and sometimes steel. Many requirements had to be met, the most important being minimizing of troubles due to corrosion. In recent years lined steel pipe—lined or coated inside and out with a

SIZE AND CHARACTER OF TYPICAL STEEL PLANT

STEEL MAKING CAPACITY—INGOTS.....2,000,000 net tons per year; 7,500 net tons per day

FINISHED STEEL....1,600,000 net tons per year; 6,000 net tons per day

COMPOSED OF:

- BLAST FURNACES
- BESSEMERS
- OPEN HEARTHS
- SLABBING AND BLOOMING MILLS—STEAM DRIVEN
- FINISHING MILLS—ELECTRIC DRIVEN

AREA.....0.5 square mile

POPULATION.....3,500 men (maximum day turn)

ELECTRIC POWER GENERATION.....Part by steam, part by blast furnace gas

BLAST FURNACE WIND.....Part by steam, part by blast furnace gas

MILL DRIVES.....Part by steam, part by electricity

STEAM LOAD.....1,000,000 lb. per hr.

TOTAL WATER REQUIREMENTS.....200,000,000 gal. per day

UNIT WATER CONSUMED PER NET TON STEEL.....35,000 gal. or 150 net tons

bituminous compound, concrete or even rubber—has been developed to supply one answer to these difficulties.

Pipe sizes should be calculated and selected liberally to allow for incrustation, coating, and to provide for future expansion. This fact is very important as an additional line, after a building or mill is completely built up, becomes a very expensive proposition, whereas adding one or two sizes to the original calculations will add little to its cost but may double its carrying capacity.

Most water services require volume not power or pressure, and the head required is only the head required to lift it to the top of the highest consumer plus the gravity head to overcome pipe friction and velocity head. Any small bottleneck—which would remain unnoticed in a high pressure power service system—will create trouble. Besides representing a large waste of power—and with the large volumes handled in a steel plant, these wastes become sizable—this trouble becomes a haunting nuisance and many a distribution system has been condemned when only a few feet of pipe, a fitting, or a valve has been guilty.

Usually the various water systems are so interconnected that, in an emergency, one may be substituted for the other or any section isolated without interruption of the service. Where so arranged, special care must be taken against accidental contamination of the services requiring purity or cleanliness of supply.

The various waters of a steel plant are prepared and treated as production requirements demand. The control over such processes is supplied by various laboratory analyses.

Process control, cost accounting, and analysis make metering desirable and, in many cases essential. Special waters, all purchased waters, boiler feedwater, condensate return, and a few special services are normally metered by recording and integrating meters at inlet and important points of distribution. Continuous metering of general service water is sometimes too cumbersome and expensive to be warranted. Instead, provisions may be made for periodic pitot tube measurements. Accordingly any proposed water metering problem should be considered rationally and only that degree of refinement employed which can be justified in each particular case.

Direct recirculation may be practiced with water which has been used in the one of the many cooling applications which result in comparatively low temperature rise, while water used where temperature rise is high and which is poluted with scale, oil, or acid must be filtered and artificially cooled in spray ponds or cooling towers before it is returned to the system. The amount of recirculation depends upon the adequacy and quality of the supply.

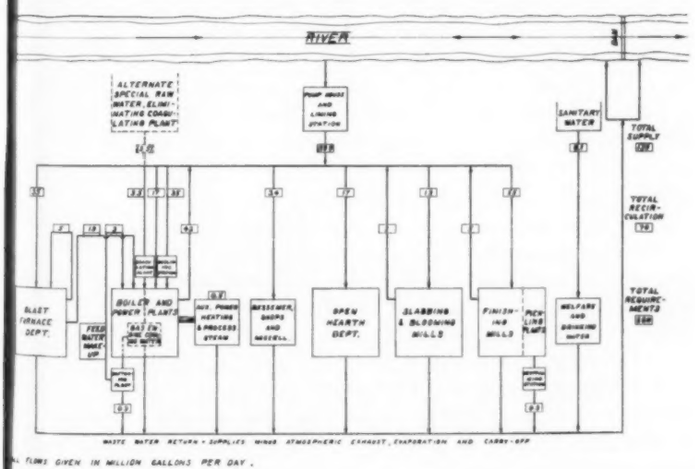
In some cooling circuits, such as gas engine cooling, etc., higher efficiencies of equipment are obtained by recirculation permitting the water to reach 160 to 180 degrees F. The heat thus added may be conserved by sending the discharge from such service to feedwater make-up, pickling vats, and other users which are able to take advantage of high temperature water.

DESCRIPTION OF SERVICES

The boiler and power plants, which include boilers, blowing equipment, electric power generators, mill drives, pumps, air compressors, locomotives, etc., are large consumers of water. The power plant alone is equivalent to the plant of a medium sized city.

The largest water consumers of the power plant, as well as the steel plant, are the condensers whether they be of jet or surface type. Consenser water generally receives prior consideration insofar as service water is concerned. Turbine condensers, especially, will receive

FLOW DIAGRAM OF WATER SUPPLY OF TYPICAL STEEL PLANT



ALL FLOWS GIVEN IN MILLION GALLONS PER DAY.

WATER - AS USED IN A TYPICAL STEEL PLANT

GENERAL CLASSIFICATION BY USES

ALL FIGURES ARE APPROXIMATE ONLY

WATER SERVICES		SYSTEM PRESSURE-LBS. PER SQ. IN.	VOLUME-MILLION GALLONS PER DAY	PERCENT OF TOTAL VOLUME	PERCENT OF TOTAL COST
COOLING					
COOLING BY MIXTURE	-JET CONDENSERS	15	35.0	18.0	8.0
COIL OR JACKET COOLING	-SURFACE CONDENSERS	15	30.0	15.0	7.0
	-FURNACES (BLAST, O.H., PIT, HEATING FCES)	20 - 60	35.0	18.0	11.0
SPRAY COOLING	-MILLS(ROLL COIL, ROLL NECK COOL., PLANOT SPRAYS, INCL. SCALE FLUSH.)	20 - 60	65.0	32.0	21.0
	TOTAL		165.0	83.0	47.0
MISCELLANEOUS					
WASHING AND WETTING	-BLAST FURNACE GAS, ORE, SLAG, ETC.	20 - 60	15.0	7.5	5.0
PRESSURE SERVICES	-HYDRAULIC	300 - 700	1.5	0.5	4.0
	-DESCALING	300 - 1000	7.5	4.0	23.5
FLUSHING AND SLUICING	-ORE, ASH, DUST, ETC. (EXCLUDING SCALE FLUSHING)	20 - 300	1.0	0.5	0.5
PROCESS AND MISCELL.	-PICKLING, CLAY MIXING, OAKITE, ETC.	20 - 60	3.5	1.5	1.0
	TOTAL		28.5	14.0	34.0
SPECIAL					
GAS ENGINE JACKET COOLING		20 - 60	3.4	1.5	6.0
FEEDWATER MAKE-UP	-BOILERS, LOCOMOTIVES AND LOCOMOTIVE CRANES	20 - 60	3.0	1.45	12.0
WELFARE AND DRINKING WATER		20 - 60	0.1	0.05	1.0
	TOTAL		6.5	3.00	19.0
	GRAND TOTAL		200.0	100.00	100.0

TOTAL REQUIREMENTS ---------- 200,000,000 GALLONS PER DAY

TOTAL RECIRCULATION ---------- 70,000,000 " " "

TOTAL SUPPLY REQUIRED ---------- 130,000,000 " " "

the water first, while coolest, in order to obtain the most effective vacuum possible. As the temperature rise through the condensers is very small, on the order of 15 degrees F., it is collected and pumped into the general service water system, there to be recirculated to the blast furnaces, open hearths, heating furnaces, etc.

Of the remainder of the water services in the power plant group, the boiler feedwater is the most important. This should include condensate return whenever possible to conserve the chemicals of treatment as well as the heat. The make-up should include gas engine cooling water and other high temperature sources, if possible, in order to reduce load on feedwater heaters.

The blast furnaces are large consumers of water with some points of consumption 60 ft. or more above yard level. Water is used mainly for coil or jacket type cooling with but little rise in temperature. It may be collected and run by gravity to wells for recirculation through the general service water system. The services include cooling of shell plates, bosh plates, tuyeres, cinder and iron notches, hearth plates, and, in emergency, cooling around the furnace foundation.

A rather large quantity of water is used for gas washing. This water, which becomes contaminated with heavy, highly abrasive flue dust, is collected in large settling basins where the flue dust settles out before the main portion of the water is run off into the sewer. It is frequently possible to retrieve part of this water and recirculate it through the lower or preliminary stages of the gas washer and thus take advantage of its high temperature. Since the gas is saturated at the exit temperature it is usually advisable to use water as cool as available in the final stages of gas cleaning in order to minimize the moisture content of the gas.

Other water uses at the blast furnaces are for flushing ore cars when dumped, cooling water for pig casting machines, flushing precipitators, cooling water for blast conditioning equipment, for flushing and cooling at the sintering plant, sealing gas holders, cooling hot blast and chimney valves of stoves, and many other smaller consumers.

The chief uses of water in the open hearth department are for coil and jacket type cooling of the back and side walls, doors, gas ports, and stack valves. The temperature rise is fairly high, running up to 50 degrees F. or more. If the open hearth is at the end of the system, the outlet water is run off into the sewer. Otherwise the water may be pumped back into the general service water system.

Besides the services mentioned, in some plants the open hearth uses water for hydraulic operation of furnace doors, reversing mechanism, and ingot strippers. It is used at gas producers for cooling and sealing.

At the bessemer plant water may be used for hydraulic operations such as tilting the vessels, ladle crane operation, ingot buggy manipulation, and ingot stripping.

The rolling mills as a group are second only to the power station as a water consumer; part of which is used by the heating furnaces, part in the mills proper, and part in the processing and finishing.

Water used by the furnaces is of the coil or jacket cooling type and may be collected and recirculated in part or whole depending upon its outlet temperature. In the ingot heating furnaces of blooming and slabbing mills, water is used for cooling stack valves and gas valves where high temperature fuels are used. In the reheating furnaces of finishing mills, water is used chiefly for cooling of skids and in some of the older furnaces for roof cooling, also for cooling outlet dampers.

About 80 per cent of the water used on the mill proper is for roll cooling, descaling, and power services. This water serves incidentally to carry off scale and other foreign material from rolls and product. This is true also of process water as used by the finishing departments.

Roll cooling is important as a means of keeping the rolls at temperatures conducive to long roll life and to keep the working surfaces of the roll free of objectionable scale particles and other foreign matter.

In recent years non-metallic or composition bearings have gradually replaced brasses for many roll-neck applications. These bearings, which have proven highly efficient and economical, use water for lubrication and nearly double the water requirements of a roll stand.

Descaling water is commonly used at 300 to 1500 lb. per sq. in. pressure. It is directed at a steep angle to the hot bar or strip, loosening by the knife-like action of the high velocity jet most of the scale which remains after the bar passes through scale breakers as well as scale which develops as the bar travels through the mill. This is the most expensive untreated service water due to its high pressure and requisite fine straining.

There are also the fire protection, welfare, and drinking water services which are self-explanatory. There are some services which would be classed as special processes and miscellaneous. It is sufficient to say that they are many and diversified.

CONCLUSIONS

Water requirements of the steel industry have increased considerably as compared with early days of the industry. Many water services now using large quantities were unknown in the early days, or even a few years ago, such as lubrication of composition bearings, cooling of completely water-cooled furnaces, product cooling, and descaling sprays. Even the older uses of water required comparatively less water per ton of finished product than they do today. Therefore, it may be expected that water requirements in the future will also increase as production speeds increase, expansions in capacity are effected, and new water service developments occur.

In the past corrosion of lines and coolers was assumed to be an unavoidable evil, and surface of the product was not so important as it is today. These conditions have been corrected by effective preparation and treatment as well as by proper application of water. The field for further development of this sort is still large and demands occasioned by new products and by the necessity for continually improving the quality of product will be met, in part, by extended water services and treatments.

In contrast, river flows and quality of the water have decreased with the additions and growth of other industries. This makes it imperative to use more and more

recirculation and artificial cooling and the accompanying chemical treatment and conditioning.

Many schemes for clarification, recirculation, and forced cooling of water which are not now sound economically may become so in the near future.

As the water cost is a moderate portion of the total cost of steel production, a cent spent here and there to improve services, and thereby steel quality, may be a cent well spent. However, as steel is a highly competitive product, every cent saved in its production counts heavily. For this reason the raising of the efficiency of some services and the elimination of unnecessary services are of great importance.

In closing it might again be pointed out that the trend in steel mill water requirements is toward greater consumption with much closer regard to water quality.

SYSTEMS and EQUIPMENT for Steel Mill Water Distribution

By H. M. Graham

DRAVO CORPORATION

PITTSBURGH, PENNA.

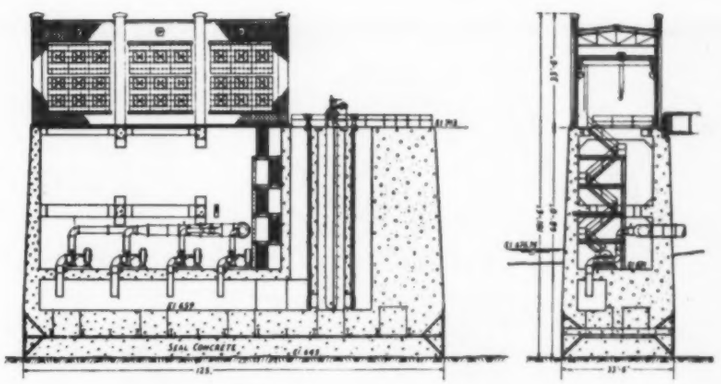


Figure 1—This well designed intake and pumphouse is located in the river near the harbor line.

▲ THE purpose of this paper is to discuss steel mill water distribution equipment including types of systems, intakes, and pumping apparatus.

Owing to the limited time available, account cannot be taken of all the distribution problems, of the many uses to which water goes in a modern steel plant, nor the various sources of supply. We shall deal chiefly with the main plant service water system and, perhaps, several of the major sub-divisions.

The principal sources of water supply for steel mills and industrial plants are rivers and lakes, since these plants are usually built where abundant water supply is available.

In general, the steel mill water system is like that installed in many of the larger cities except there is less accent on appearance. The steel mill system is rugged in design, as foolproof as possible in operation and maintenance, but at the same time it should be highly efficient.

In the larger mills greater quantities of water are pumped each day through the intricate distribution systems, than are used by many of our larger cities. In these mills a service usage of 150,000,000 gallons per day would certainly not represent the peak capacity. This amount of water is greater than the City of Pittsburgh handles at its Ross Pumping Station where the daily capacity is approximately 100,000,000 gallons.

The service water is ordinarily handled by one or more main pumping stations located at the source of supply, and connected to an intricate discharge system. In this respect the system is again similar to a municipal installation which, with all the maze of piping, is at some point connected to a storage reservoir.

In the steel mill, a standpipe is the storage reservoir, and while this usually does not hold a large volume of water in comparison with the amount used, it operates as an equalizer on the system to iron out fluctuations in pressure and demand, and to provide for a small emergency supply when this is needed.

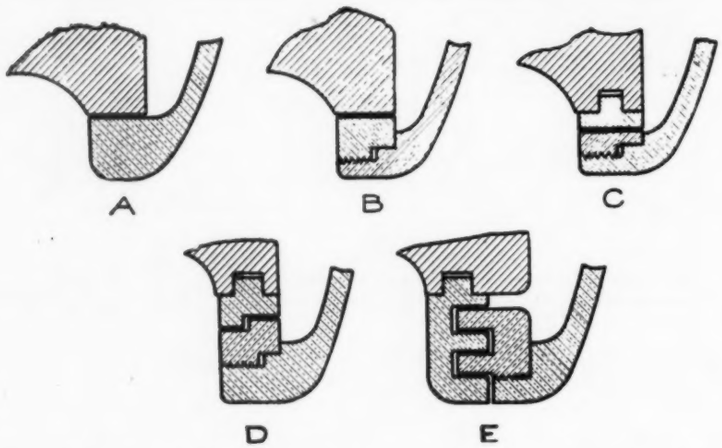
Probably the usual mill standpipe will impound in the neighborhood of 300,000 to 500,000 gallons. This figure is given only as an average since there are, no doubt, mill systems with storage facilities far in excess of this.

The usual mill water system will be operated at pressures of from 35 to 50 lb. per sq. in., which pressures are adequate for normal purposes. The uses to which service water is put are many, but in general the larger quantities are used for cooling around the rolling mills and the blast furnaces.

Large quantities of cool water are required in the average steel mill for condenser service, and the equipment for pumping the condenser water is frequently separate from the main water service supply, since the pressures required are considerably lower. This is par-

ticularly true since plants which formerly used barometric condensers in the days when steam engines were in general use, have now changed over to surface condensers, with the steam turbine the predominant prime mover.

Many steel mill condenser water systems simply take the water from the source of supply, pass it through the condensers, and then discharge back to the waste system. However, there are some plants which boost the condenser water after it has passed through the surface condensers, into a system of higher pressure, either the main service water system, or to some other pressure system as may be required. For example, in one plant the condenser water from the main power house is boosted by electrically operated pumps to the blast furnace department, where it is used for cooling purposes. There is a cross tie between this system and the main service water system, so that interchange between the two may be made at any time. In another plant, surface condenser water is taken from the mill



A—plain flat joint without protecting rings; B—wearing ring on impeller only; C—rings on both casing and impeller; D—offset wearing rings; E—perfected De Laval labyrinth rings.

Figure 2—Sketches showing the evolution of wearing rings from the plain joint to the labyrinth ring.

supply line, passed through the condensers, and back into the supply line through the use of booster pumps.

It would be impracticable to here describe the many modifications to types of systems in use in the steel mills. It may be interesting to speak about some of the problems encountered in handling mill water, and about equipment used to pump it. In the Pittsburgh district, mill pumping and distribution systems are seriously affected by corrosion due to acids in the supply. A problem of great importance is the elimination of the corrosion difficulties. Centrifugal pumps with acid resisting bronze interior parts and casings, have been used with considerable success, although in the larger sizes they are quite expensive in first cost.

Another method to take care of this corrosion problem is to neutralize acids with lime which is added to the water at the intake, in either a wet or dry state. Although the first cost of equipment for either dry or wet feeding of lime at the intake is not so great, this method of solving the corrosion problem may be expensive in the long run, for it should be continued during the acid periods if complete protection to pumping and distribution equipment is to be obtained.

The rivers of the Pittsburgh district also produce during certain times of the year a condition of alga growth in distribution lines, and especially in condenser tubes. This trouble is sometimes very severe and is expensive to handle, since it makes frequent cleaning necessary. One of the methods successfully used to eliminate alga growth, is the use of chlorine applied either at the intake of the water supply, or at some point close to the location of the particular apparatus where the alga growth is troublesome.

While most of the water supplies for mills remain untreated and unfiltered except as just mentioned, a few plants are equipped with complete water treatment. Within the last few years a large plant was built in the Pittsburgh district with its river water supply settled, treated, and filtered before being turned into the plant system.

Probably the simplest type of intake is a pipe running out into the source of supply, and protected at the end by a crib. Most of the larger steel mills, however, use concrete intake structures of ample size, equipped with stationary double screens. These screens can be lifted from the intake openings for cleaning purposes, and they are usually satisfactory for normal river conditions. The rotary or traveling type of screen, although more costly, is a better device, particularly if much floating material is present during flood stages, or if ice is prevalent.

In a well designed water intake, the main opening from the water supply is equipped with bar screens to keep out heavy floating material. Between the bar screens and the pump suction well is the location for the stationary cross mesh double screens, or the traveling screen. It is important to keep the velocity of water entering the intake as low as possible, and entrance velocities of 2 to 3 ft. per sec. are desirable. In any case, if possible, the velocity of the water entering the intake should be less than the velocity of the stream from which the supply is taken.

An example of a well designed intake and pump house is shown in Figure 1. This intake and pump house is located in the river near the harbor line. It was built by the steel floating pneumatic caisson method.

This caisson, 125 ft. long by 33 ft. 6 in. wide was constructed at Neville Island, launched, towed down the Ohio River to the job location, where it was sunk and sealed on solid rock 31 ft. below water level. The height of the structure from rock to top of concrete is 68 ft., and above this is the brick super structure of the pump house.

Water enters the screening chamber of the intake at right angles to the flow of the river, near the upper end of the pier. The passage through the screening chambers to the pump suction well is in a direction parallel with the river flow. Entrance to the screening chamber, where the rotary screen is located, can be blocked off

by means of suitable gates for repairs to the screen. This construction also makes it possible to unwater the pump suction well when this is required for any purpose.

For best results the bottom of the intake opening should be located at or above the bed of the river, and the top of the opening should be below pool stage. When building a pump house intake, the site selected should, if possible, be away from the line of drift of the stream in which it is located.

Although the traveling or rotary screen is used primarily on the larger installations, there are times when its use is justified with small intakes. For example, the speaker recalls an intake at one of the smaller industrial plants located on a shallow stream, where it was almost impossible to operate during the freezing months of the year, owing to formation of ice in and near the intake chamber. By the installation of a mechanical traveling screen, ice formations were kept broken up, and packing caused by ice, leaves, and other debris was almost entirely eliminated. The traveling screen in this case very quickly justified its use by the saving in labor it accomplished.

For the pumping of main water supplies in steel mills, centrifugal pumps have been used almost universally for many years. In some plants the steam turbine is the favored prime mover, whereas in others, there seems to be a definite trend toward electric motor drive. During the last twenty years there has appeared a considerable improvement in the efficiency of centrifugal pumps. Up to 10 per cent increase in efficiency has occurred on large pumps, and from 15 to 20 per cent on small pumps. Likewise much improvement has been made in steam turbines for driving these pumps, resulting in an increase of overall duty. Probably this amounts to 20 per cent.

Efficiency of electrical equipment has also been stepped up and improvements in other ways have been made. As a result of this, some old pumping plants in steel mills have been modernized by the installation of new equipment, whereas others would find this profitable to do.

Today large centrifugal pumps can be obtained with efficiencies as high as 89 per cent, and if motor drive is used, with overall wire to water efficiencies as high as 85 per cent.

In addition to having high initial efficiency, a pump should be able to sustain this efficiency over long periods of operation. The efficiency of the centrifugal pump is affected chiefly by the wear which occurs at the clearance between the casing and the rotating impeller. As leakage increases at this point, more water short circuits in the pump and less goes out into the pressure system. This leakage cannot be seen so that it is possible for pumps to operate for long periods at much reduced efficiency unless tests are made at regular intervals. Sometimes the clearances between the pump casing and the rotating impeller are made very small in order to make possible the guaranteeing of high initial efficiency; but due to grit in the water being pumped, bearing clearances, and shaft deflections, these close clearances cannot be maintained. To make it easier to restore the initial efficiency of a pump after wear has occurred, most large centrifugal pumps are supplied with removable impeller and case wearing rings. The design of these wearing rings is quite important, since upon this depends the length of time the efficiency of the pump when new, will be sustained.

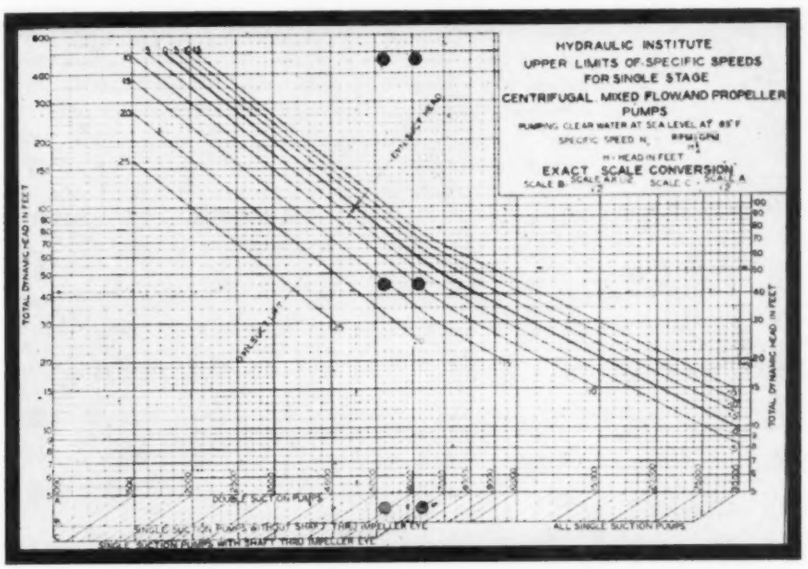


Figure 3—Chart from which specific speed can be determined if total dynamic head and suction lift or pressure are known.

Figure 2 shows the evolution of wearing rings. The labyrinth type of ring as shown at "E" has been used for a number of years to achieve and maintain high efficiency in centrifugal pumps, without having to use close clearances. Although this type of wearing ring has been widely used, it is, perhaps, only recently that users of centrifugal pumps have come to truly appreciate its advantages over the plain or flat ring.

Several examples can be cited here to illustrate the sustaining effect of the labyrinth ring on initial pump efficiency. These pumps handle filtered water, and while similar experience may not occur in every plant, par-

ticularly where acid or gritty waters are being handled by centrifugal pumps, the experiences show that there are important advantages to be secured through the use of the labyrinth type of wearing ring.

A single stage pump having a capacity of 15,000 gal. per min. against a head of 175 ft. was tested when installation was made, and again after seven years of continuous operation. The loss in efficiency during this period of use was only about 1 per cent. During the seven year operating period no parts of the pump had been renewed or repaired.

Another example of sustaining high initial efficiency was demonstrated at another plant where two 35,000 gal. per min. pumping units after six years of service, which averaged 18 hr. per day, showed practically no change in efficiency. Likewise during this period of operation the pumps received no repairs or renewal of parts.

Not so many improvements have been made in the mechanical construction of centrifugal pumps during recent years; the refinements to pumps being more or less of a minor nature. There has been a rather recent tendency to use ball bearings for some sizes of centrifugal pumps, and this has brought about a somewhat different problem in the matter of maintenance, since lubrication of the ball bearing equipment differs greatly from the fundamentals of plain or sleeve bearings.

Pumps equipped with anti-friction bearings can be lubricated with either grease or oil. The grease lubricated bearings, however, have a definite advantage, since grease is more easily confined in the bearing housing. Its use simplifies the problems of housing design and bearing maintenance. The use of grease also makes it possible to have a very clean installation, since there is practically no seepage of the lubricant from the bearing housing, even in the case of vertical pumps.

It is important to understand that the choice of lubricant, whether grease or oil, is entirely a problem of design and not one of maintenance. Once a pump has been designed and built for one type of lubricant, the other type cannot be satisfactorily used.

It has been the writer's experience to find that frequently, in industrial plants, pumps having ball bearings are improperly lubricated. While a certain amount of grease is vital to the operation of a ball bearing, most operating difficulties have been caused by over-use of grease. All the bearing needs is a small amount of grease properly distributed over the running surfaces. This small amount will provide satisfactory lubrication for a considerable period. If a large volume of grease is placed in a bearing, a high operating temperature will usually result. In general, it is important that the supply of grease be limited to not more than half of the capacity of the housing.

Properly designed pump bearings of the ball type should have drain outlets or relief fittings to prevent over-lubrication. At least once a year a grease lubricated ball bearing should be thoroughly cleaned of old grease and filled with new.

Sometimes in the operation of large centrifugal pumps, noise and cavitation occur which often result in corrosion or erosion of the interior parts. Experience and research have disclosed that almost without exception difficulties of this kind can be traced to pump speeds too high for the conditions of operation. The highest speed at which a centrifugal pump may be operated with freedom from cavitation and noise is a function of capacity, head and suction conditions. Centrifugal pump builders have for the most part accepted the recommendations of the Hydraulic Institute as to maximum operating speeds. The recommendation represents the best experience of the manufacturers. When centrifugal pumps are selected for any application it is important for the purchaser to know, that for the conditions of operation, the pumps will probably be free of cavitation. It may be interesting at this point to explain just what cavitation is and what may happen to a pump subjected to it. If the speed of a pump is too high the liquid being pumped may, in localized areas on the suction side of the equipment, be caused to have its pressure reduced to the vapor pressure or boiling point. If this occurs, cavities or empty spaces are formed into which the liquid vaporizes. The gas or vapor in these spaces or cavities is carried along in the pump until a place of higher pressure is reached, when the gas pockets collapse with severe shock to adjacent vane or impeller walls. This shock may cause mechanical destruction, which is sometimes apparent as a boring action to which the term erosion may be applied. Chemical reactions may also take place between the gases and the metal, resulting in corrosion and additional destruction.

From the above, it is evident that cavitation is accompanied by noise and sometimes by vibration, shaft breakage, and reduction in capacity and efficiency.

The specific speed of a pump is defined as the speed at which a pump designed for one gal. per min. would operate when working against a total dynamic head of 1 ft. The formula for specific speed is:

$$N_s = \frac{\text{Rpm.} \sqrt{\text{Gpm.}}}{H^{3/4}}$$

where N_s = specific speed
Rpm. = revolutions per minute
Gpm. = gallons per minute
H = total dynamic head, feet

The specific speed chart issued by the Hydraulic Institute is shown in Figure 3. If total dynamic head and the suction lift or pressure are known, the specific speed can be determined from the chart. Then, if this specific speed is substituted in the above formula, the equation may be solved for the Rpm. which is the recommended maximum speed at which the pump in question should be operated. For example, if a 10,000 gal. per min. pump is to operate against a total dynamic head of 150 ft., with a suction lift of 15 ft., from the chart the specific speed is found to be 2600. Substituting this specific speed in the formula, the maximum speed at which this pump should be operated to probably avoid cavitation would be 1080 rpm. Sometimes the speed of centrifugal pumps is increased above the designed rpm. after initial installation. If so, it is important to check the speed against the specific speed chart in order to make sure that the pump will operate within recommended practice.

The centrifugal pump installation for handling the main mill supply should be installed with a suction line as short as possible, with a minimum number of fittings. It is preferable to have the end of the suction line belled

out so the velocity at entrance will be very slow. This also reduces the entrance loss. The bell should be so shaped that the water is gradually speeded up to the normal velocity in the suction pipe, which should not exceed 4 ft. per sec. for best results. No point of the suction line should be higher than the top of the inlet nozzle of the pump. If such is the case, air pockets are apt to develop which may cause erratic pump operation and possibly cavitation.

The submerged end of the suction pipe must be sufficiently long to prevent setting up of whirl pools from the water surface down to the inlet. When this takes place, air is drawn into the pump with the water. This not only reduces the water capacity of the pump, but establishes the conditions for corrosion and erosion as mentioned previously.

Velocity of water in discharge lines does not influence pump operation. It has principally to do with the horsepower required to drive the water through the system. Ordinarily, velocities not to exceed 8 ft. per sec. in discharge lines are desirable, since beyond these figures excessive friction losses occur. Some steel mills use discharge pipe line velocities between 5 and 8 ft. per sec. Best municipal water works practice is 5 ft. per sec. When the costs of pump power and of pipe are carefully considered, a satisfactory conclusion about line velocity can usually be reached.

For high pressure work, multi-stage centrifugal pumps are used in most of the steel mills. They are principally in boiler feed, descaling and general hydraulic system service. For mechanical reasons, the maximum number of stages in a single casing will probably not exceed seven, and speeds of 3600 and 1800 rpm. are used.

A high degree of development has been reached in the design and construction of hot water pumps for boiler feed service. Much has been accomplished in the selection of suitable materials for them. As a result, multi-stage pumping equipment is available today for boiler plants of the highest pressures, and with the same assurance of reliability as for low pressure plants. Installation of hot water pumps does require careful study, for it is important to establish efficient suction pressures.

Many multi-stage pumps for hot strip mill descaling purposes have been installed for capacities of 1000 to 1500 gal. per min. at pressures up to about 1300 lb. per sq. in.

In closing, it is desirable to mention the fact that, although there has been a tendency to install motor driven centrifugal pumping equipment in steel mills, it nevertheless remains true that there is greater economy in the use of steam turbines for driving large centrifugal pump machinery. Probably the dividing line is somewhere around 500 hp. Where the power required to drive the pump is in the neighborhood of 500 hp. or higher, excellent economies are possible with the steam turbine drive of today. Furthermore, the turbine drive permits greater flexibility of pump operation, and the utmost reliability of continuous service.

Effect of Water Upon EQUIPMENT and PRODUCT in the Steel Plant

By H. H. Shakely

General Master Mechanic and

C. J. Wyrough

Supt. Fuel Efficiency and Combustion Dept.

JONES & LAUGHLIN STEEL CORP.

PITTSBURGH, PENNA.

▲ IN a discussion regarding the effect of water upon equipment and upon the product the source and analysis of the water must be considered, as waters which vary either in degree or type of acidity, alkalinity, algae content and other constituents will require different treatments and will produce different results. The water covered in this discussion is from the Pittsburgh District of the Monongahela River. This water is generally acid, the temperature varies from 33 degrees F. in the winter time to about 90 degrees F. in the summer time and while it is generally clear, after heavy rains it is thick with silt. It is quite obvious that physical and chemical treatment of this water is necessary to make it suitable for plant use. The chemical treatment is given at the water inlet where lime is added in sufficient quantities to overcome the acidity, and all of the water passes through screens either stationary or revolving. These screens vary from ½ in. to 1 in. mesh but do not remove the fine particles and the silt above mentioned.

The first effect of this water on the equipment is noticed in the river pump house and it is found that with cast iron water chambers, bronze impellers and wearing rings that there is a gradual deterioration of the various parts. Where the case wearing ring fits into the case the iron cuts away from the ring until the leakage which develops becomes so bad that the chamber must be built up and new grooves cut and new wearing rings fit. The wear on the impeller is mostly at the tips of the discharge vanes which become badly honey-combed, and if the impeller seal rings are screw fit the threads become wasted away and the seal rings become loose. If the pumps are turbine driven with a

surface condenser it is necessary to clean the condenser tubes frequently in order to remove the coating which interferes with the heat transfer of the condenser and reduces the vacuum. This condition is also true of any surface condenser in operation in the plant which utilizes this kind of water. On centrifugal hydraulic pumps in the plant the same trouble is experienced as with the lower pressure pumps except in a larger degree and semi-steel casings have been cut out very rapidly, making it necessary to reline them at the case ring fits with stainless steel. On the reciprocating high pressure pumps excessive wear is experienced when the river is dirty and there is a great deal of damage done to the valves and seats. Plunger packing also wears out rapidly under these conditions. There is so much of this water used that filters or settling basins are not always practical, although in some cases, especially where the high pressure water is to be used for spraying steel, proper filtering must be provided for clean water.

Going to the by-product coke oven plant we find that water is used at the primary coolers, wash oil coolers, tar acid plants and for quenching coke. In the primary and wash oil coolers it is necessary that good heat transfer be maintained which means that the cooling pipes must be kept clean. This is accomplished in the primary coolers by turbining the pipes to keep them free of accumulations and in the wash oil coolers by means of scrapers and scaling hammers. The piping in these units must be very carefully inspected as a leak in the primary cooler allows water to mix with the weak liquor and causes excess liquor to be distilled. In the wash oil cooler a leak would cause loss of oil, and at the tar acid plant a leak would allow the water to mix with the acid and render it useless. The temperature of the water entering the by-product also affects operations because in the summer time when the water gets warm the temperature of the wash oil cannot be reduced properly, which results in a loss of by-product yield.

Proceeding to the blast furnaces we find that water is used in large quantities for cooling the tuyeres, cinder coolers, monkey coolers, and bosh cooler plates on the furnaces, for hot blast valves on the stoves, for quenching slag and for gas washing. Screened but unfiltered water properly treated to neutralize any corrosive or other harmful ingredients and delivered at sufficient pressure to provide the required supply is usually satisfactory for all cooling purposes and for slag quenching. This quality of water is also satisfactory for gas washers of the hurdle type or any other types where large openings are used, but in the type where small impinging plates or any kind of spray nozzles are used, strainers with screen openings, not in excess of $\frac{3}{16}$ in., must be provided and careful attention must be given to keep the strainers clean. The water used for the aforementioned purposes does not come in contact with any product and therefore does not affect it. Any leaks, however, in the tuyeres, bosh cooler plates or hot valve cooling system which allows water to get into the furnace has a very bad effect on furnace operation and upon the quality of the iron. It is extremely important that water be kept out of the furnace. In fact this matter is of such importance that steps are being taken to reduce, to the lowest possible degree, the amount of moisture entering the furnace with the blast. This is one of the few places in the manufacturing process of steel where water becomes one of the ingredients of manufacture and affects the quality of the product.

Insofar as the effect upon equipment is concerned, the chief trouble experienced with the equipment around blast furnaces is in the pipe lines and is due to the lines being plugged with resulting overheating.

At the open hearth water is used for cooling purposes also and is provided for doors and frames, fuel burners, chills and certain types of ports. Hydraulic water is used for door operations and reversing valves although in more modern plants this work is largely done by electric motors. Water is also used for slag cooling which, incidentally, provides one of the greatest hazards at the open hearth in the form of slag box explosions. Great care must be exercised to be sure that no moisture is present at the bottom of the slag box before slag is poured into the box, and care must also be taken that the slag buggy has been under the cooling spray sufficiently long before being sent to the slag dock for breaking. As the water does not come in direct contact with the product, no bad effects on the product are experienced from this source. The chief trouble experienced with water at the open hearth is due to leaks around the furnace which permit water to spray on the hot brick or on any refractory brick.

On the blooming mills water is used in large quantities on rolls for the primary purpose of cooling but it also serves at the same time to keep scale washed off the rolls and prevents surface defects on the steel which might otherwise result from scale adhering to the rolls. If voluminous quantities of water were not used rolls would quickly become hot and firecrack before any production would have been obtained from the rolls. As it is, even with the use of large quantities of water, rolls do become firecracked and must be taken out of service and dressed. Firecracking consists of checkered cracks in the surface of the rolls caused by the intesne heat to which the rolls are subjected, and firecracked rolls cause surface defects in rolled steel. Water also assists in keeping the surface of the rolls from becoming too hard and the result of what would happen if water were not used can easily be seen when something happens to stall the mill with a piece of hot steel in the rolls. The surface of the roll in contact with the hot steel becomes so deeply firecracked and so hard that when the roll is dressed an extra deep cut must be taken and the hard spot slows up the dressing process. This not only increases the cost of dressing the roll but also greatly reduces its life—a satisfactory development for the roll maker but no so good for the man paying the bills. If water were not used the heat and pressure under which the rolls work would soon distort them so badly that it would be impossible to hold the section and the expansion would result in such high bearing pressures that extra power would be required for driving the mill and the chances are that the number of broken necks would be greatly increased. Water is also used for sluicing loose scale that has dropped through the table rolls to the pit beneath, and for cooling shear knives. The requirements for the water used in the blooming mills are that it be free from any corrosive matter and sufficiently free from foreign matter so as not to clog the pipes. Sufficient care must be taken to

prevent water from getting into the oiling systems on the table rollers as such an occurrence not only ruins the oil but also results in excessive bearing renewals and delay on the mill.

Hydraulic water at the blooming mills is used for manipulators and shears and in some mills for the operation of lifting tables and other pieces of equipment. The trouble experienced on the hydraulic system with water is both in the pumps and operating valves, and the maintenance of the type of hydraulic valves using leather cups is practically a continuous process.

At the rolling mills the use of water is very similar to that in the blooming mills, the largest amount being used for cooling the rolls for the same purposes as mentioned before. Water used for this purpose can cause some peculiar delays on mills even though no permanent damage is done. On one occasion in the winter time a mill was starting up after a shutdown, the water had been turned on the rolls and the signal was blown to roll it over. The engine just wouldn't roll the mill and there was no better success after the slack had been taken and the mill kicked four or five times. An investigation to ascertain the trouble was then started and when nothing could be found on the engine which could be responsible for the condition the mill was looked over and it was found that ice had formed between collars of the top and bottom rolls and this was holding the mill. A steam jet removed the ice and the mill proceeded.

Some of the greatest damage to equipment from water can occur in the winter time and during cold weather great care must be taken to prevent freeze-ups and attendant damage and this can be successfully accomplished only by covering pipes, proper use of salamanders or other types of heating devices or by bleeding. Some people attempt to do the whole job by bleeding, and to be doubly sure about it they open their drains about November 1st and keep them on until April 1st. If on some fairly warm day attention is directed to the fact that the excessive bleeding is going to make somebody's costs high, the response is quite unfavorable but when the cost sheets come out at the end of the month the heat content of the language directed at the "exorbitant water cost" would thaw many frozen pipes. To prevent frozen lines and equipment without unduly increasing costs is an item that requires careful, systematic planning with a thorough follow through in performance. Water is also used for cooling bearings, especially with the bearings of the fabric type, and this water must be free from grit or foreign matter so as not to spoil the bearings. High pressure water is also used at the rolling mills for descaling purposes. The sprays used for this purpose must be carefully set so as to cover the entire surface of the steel, otherwise a thin strip of scale may adhere to the steel which would later cause a surface defect that would be sufficient cause for rejecting the steel. Due to the high pressure of this water the area of splash is very great and due also to the high pressure the water very readily penetrates into the oil reservoirs of table roller bearings and special provision must be made to provide a tight seal to prevent this infiltration.

Water is used on the furnaces for cooling skids, lintels, stack dampers and on gas producers for cooling pokers.

The chief requirements for all of this water are that any acidity content be overcome and that the water be as free as possible from any foreign matter that would cause stoppage in the cooling pipes.

Each type of mill has some special use of water peculiar to that mill and no effort has been made in the preceding discussion to cover each individual type, but the problems associated with the use of water in the strip mill are so numerous and varied as to justify separate discussion.

Service water is delivered to the strip mill through a 36 in. main at approximately 50 lb. per sq. in. pressure. It first passes through a ¾ in. mesh screen, then through ⅛ in. diameter self-cleaning strainers before going into the mill headers. Aside from liming to reduce acid content, this is the only treatment the general service water receives.

The strip mill uses approximately 30 million gallons of water in 24 hr., which is distributed as follows, the points of consumption being considered in the order in which they connect to the main:

(1) Service water is used in the motor room on all air coolers, including inter and after coolers on the air compressors. These coolers are of the water tube type to facilitate cleaning, and made of red brass to resist corrosion.

(2) The above water is exhausted to a surge tank from whence it is delivered to the furnace skid pipes through a booster pump at 55 lb. pressure. In addition to this water, there is also a 1200 lb. hydraulic connection on all skids for relieving skids of silt and mud which often collects, stopping water flow. Construction has been started on a 6 in. city water supply to the furnaces for use in event of a failure of the plant system. It might be well to mention that the delivery line on the furnace booster pump is connected to the main water line through a check valve as a protection against pump failure. Pipe arrangements have also been installed whereby the entire volume of our stand pipe (on the spray system) can be used in event of an emergency.

(3) Water for the hydraulic spray system is taken from the main and passed through three pressure filters filled with crushed slag. These filters are of approximately 700 gal. per min. capacity each, and are so arranged that they can be back-washed frequently by reversing the flow of water through the bed. From this point the water goes to a stand pipe (on the pump suction line) which is 16 ft. in diameter and 72 ft. high, and then to the pumps through a 12 in. line. The pumps which are 1200 lb. pressure, 1000 gal. per min. each, 7 stage, centrifugal, are located in the mill motor room near No. 4 stand. On the suction line near the pumps a surge tank has been installed to eliminate line as well as pump shock caused by intermittent flow. When first installed, these pumps had cast iron impellers and bronze seal rings mounted in a steel casing. Serious trouble was experienced but was finally cleared up by installing stainless steel impellers, casing and seal rings in a steel pump housing that had been stainless steel lined at the ring fits. These pumps are equipped with both high temperature and low water (suction) controls. Water is delivered from the pumps to a 1200 lb. air accumulator and thence to the mill sprays through

hydraulic spray valves. The sprays are located as follows:

No. 1 scale breaker, delivery side, top and bottom.
No. 1 mill, delivery side, top and bottom.
No. 2 mill, delivery side, top and bottom.
No. 3 mill, delivery side, top and bottom.
No. 2 scale breaker, delivery side, top and bottom.

The condition of the spray system must be watched very closely since one spray faulty due to wear, dirt, adjustment, pressure or timing may result in the scrapping of tons of steel on account of rolled-in scale. The spray at No. 2 scale breaker being the most important requires the closest attention.

One point of interest that may be mentioned at this time is the effect of the spray water and scale upon machinery adjacent to sprays. Line shaft covers and gear cases in the vicinity are sealed with packing, then the joint covered with hot gear shield which hardens when cool, preventing the infiltration of most of the scale and water into oil reservoirs. This system is now in use on a number of the tables and the results at present are such that its use will be extended. Another point of trouble for which the sprays are directly responsible is the failure of the roll balance system due to sticking jack plungers. At numerous points fine scale is washed in between the plunger and cylinder, resulting in scored walls and final failure of the packing. Numerous methods have been tried to eliminate this condition, but it is felt that the one being tried at present, a vulcanized rubber boot for each plunger, will give us the best results (Figure 1). This boot fits tightly between the top and bottom back-up chocks and completely surrounds the plungers.

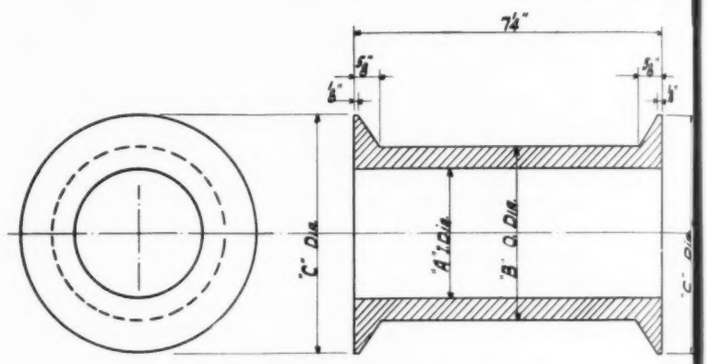
(4) Paralleling the 12 in. filtered water line through the mill oil tunnel is a 12 in. service line. This line serves the oil system coolers which are water tube type to facilitate cleaning. Water from these coolers is wasted to the mill sewer.

(5) Water for roll and strip cooling is taken from the main at a number of points along the entire length of the hot mill, the last connection being at No. 10 stand feeding the run-out table sprays. Several type sprays have been tried throughout the mill, but the arrangement in use at present consists of double sprays extending the length of the work rolls in both entry and delivery sides. The back-up rolls are cooled by a single spray on the delivery side of the top only. Close attention must be paid to the condition of these sprays to prevent serious damage to the rolls. The rolling of long slabs makes it necessary to use excessive amounts of water to prevent overheating and firecracking of the rolls.

(6) To facilitate changing of rolls, the retrieving tables and guides throughout the finishing train are hydraulically operated from the 1200 lb. system. A double acting plunger located beneath the table is operated by a 4-way valve. These plungers are very short lived, due to being exposed to scale and hot water from the strips. For this reason, stainless steel plungers are now being used in order to stop corrosion.

(7) The highest pressure system is the 4400 lb. roll balance system supplying the entire mill. Due to the fact that any small particle of foreign matter would cause serious damage to the cylinder walls or packing with this high pressure, a solution of city water and soluble oil was adopted on this system. Pressure is furnished by two triplex pumps through an accumulator then to the individual stands. Mention has been made of the trouble experienced due to the effect of scale on the plungers and it is believed that the rubber boots now in use will be a great benefit, although an additional change in the plungers is also responsible for the elimination of trouble. This change consists of a chrome plated plunger to replace the conventional basss covered type. A number of these have been in use for more than a year.

(8) Three banks of sprays are mounted over the run-out table adjustable for both width and pressure. These sprays are approximately 75 ft. from No. 10 stand and operated by remote control. These sprays are used for cooling the strip to temperatures required by the metallurgical department to meet specifications and as an aid to scale removal in the pickle line.



BELLOW TYPE RUBBER BOOT

Mark	Number required	"A" dia.	"B" dia.	"C" dia.	Where used	Stand
A	8	3'8"	4'8"	5⅝"	Back-up plungers	No. 1
B	4	3"	4"	5½"	Work roll plungers	No. 1

(9) The last point where water is used in the hot mill is at the coilers. Here each cluster of rolls as well as the pinch rolls are paralleled by a spray. It is very important that the cooling system at this point be kept in good order since failure would result in broken or worn out rolls in a very short time. A hot roll having more tendency to pick up steel might also be the cause of a number of marked coils which in turn would be scrapped.

(10) The next connection to the main is the supply for the cold mill filters. This installation consists of three pressure filters of the same type used in the hot mill except that they are charged with sand and gravel instead of crushed slag. This bed is somewhat finer and delivers water with less foreign matter than the slag filters. Water from this filter system is used at three points as follows:

(a) Batch pickler—

Before filtering water for this unit, considerable trouble was experienced in obtaining a white

pickled sheet that would satisfy the trade. After changing to filtered water this condition has cleared up and only on rare occasions is it necessary to use city water at this unit.

(b) No. 1 and 2 scrubbers—

The condition at these units was somewhat similar to that existing at the pickler and since changing to filtered water all of the numerous products passing through the scrubber have greatly improved.

(c) 93 in. and 54 in. tandem mills—

In order to meet the ever increasing demand for clean water at the tandem mills, caused by increased delivery speeds, it was necessary to change the original water supply to the three filter system mentioned above. This installation supplies all the external roll cooling water for both mills, the internal water being taken from the service line. At present the capacity is not as great as it should be, but with the aid of a booster pump satisfactory operations are maintained. Additional filters and a larger booster are now being considered. Delivery of clean water to these mills is very important since dirty water may result in marked rolls, defective surface, and possible complete scrapping of the product.

(11) As in the hot mill, service water is used exclusively in all air coolers and oil coolers, these being of the water tube type.

(12) The continuous picklers use service water piped through a jet type steam heater to help raise the temperature on refills so that tank changes can be made quickly.

(13) The cooling water for the deoxidizing gas machines is furnished from the service line through an additional strainer to remove any particles that might clog the sprays. Originally coke towers were used for primary coolers, but the amount of oxygen picked up by the prepared gas due to direct contact made it necessary to install indirect tube type coolers. This installation has worked out very satisfactorily.

To discuss each point where water may affect machinery or product would develop in much too long a discourse. However, it is felt that there is one point in general throughout both hot mill and cold mill that should be mentioned, that is the effect of water contamination of oils and greases in sleeves or roller bearings. In the first case, that of oil in sleeve bearings, constant inspection and test must be made to prevent contamination of the back-up oil. Should an excess of water be allowed to accumulate, serious damage may occur to the necks or bearings, such as etching due to acid from the water, loss of film strength due to emulsified oil, scoring of the neck or wiping of the bearing due to foreign matter such as scale from hydraulic sprays. Any or all of the above may happen if bearing seal rings are not kept in perfect shape. In the case of roller bearings, seal rings must also be maintained to protect the bearing from infiltration of water and foriegn matter. As in the case of the oil bearing, damage may result from etching, emulsification of grease or foreign matter. The grease lubricated roller bearing can be protected to a great extent by using enough excess grease to maintain a slight flow from the bearing. This practice, however, must be used with caution since overheating of the bearing may result.

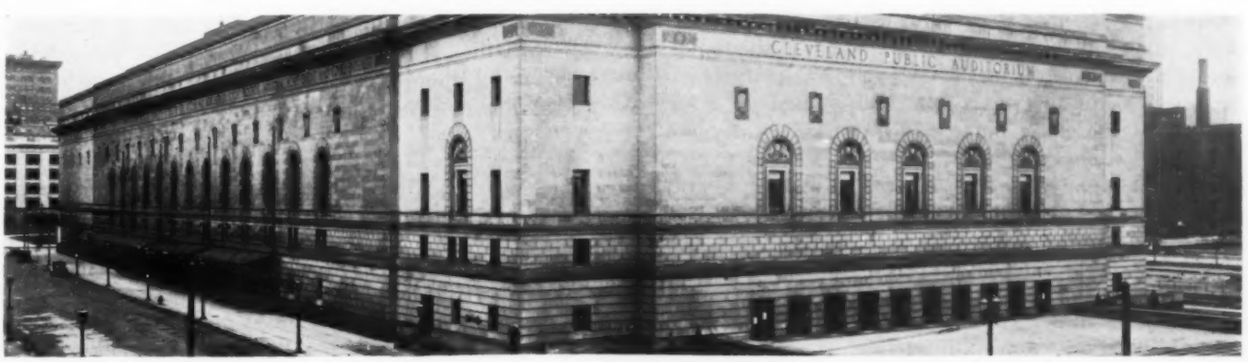
Water, therefore, can be the cause of considerable damage both to equipment and product and must be given close attention to keep this damage to a minimum.

(This symposium continued on next page.)

The plans for the Annual Convention and Iron and Steel Exposition of the Association of Iron and Steel Engineers are being developed so as to assure the members and guests one of the finest meetings in the history of the Association. The dates for this Convention are September 23, 24, and 25, Cleveland, Ohio. On page 71 of this issue will be found a tentative list of the subjects to be discussed at the technical sessions. A total of twenty-eight papers will be delivered at the three-day Convention.

Over one hundred manufacturers of steel mill equipment have now contracted for space in the Iron and Steel Exposition which will be held in the Cleveland Public Auditorium. The Exposition will be open from 9 in the morning till 10 in the evening each day of the Convention. It is also palnned to have the Exposition open on Wednesday evening, the night of the banquet, so as to assure that all plant men will have an opportunity to inspect the exhibits.

The Convention Headquarters will be the Hotel Statler. All social affairs will be held at this hotel while the technical sessions will be held in the Cleveland Public Auditorium.



CORROSION and SCALE Formation in Steel Plant WATER SUPPLY

By E. W. Butzler

HAGAN CORPORATION

PITTSBURGH, PENNA.

▲ EXCLUDING the water problems of the steam plant from this discussion, we can place the other water problems of the iron and steel industry in two distinct classes: (1) The prevention of scale formation on surfaces; (2) The maintenance of an integral film or coating on surfaces to protect them from corrosion.

Either one or both classes of problems may be present in a single plant, but usually only one represents serious trouble. In the case of a plant using raw water, high in bicarbonate hardness, the main problem will be that of preventing scale from forming on surfaces, especially heat absorbing surfaces. On the other hand, if the raw water contains little or no bicarbonate hardness, particularly if it has low pH value due to presence of industrial waste or acid mine drainage, the main problem will be the prevention of corrosion of the metal surfaces with which it comes in contact. It is generally agreed that the prevention of corrosion depends upon maintenance of a coating or film that is integral with the metal to be protected.

METHODS USED IN SOLVING THESE PROBLEMS

In the past, methods used for preventing scale deposition on surfaces frequently resulted in aggravating the corrosion of these surfaces. On the other hand, the addition of an alkaline chemical, such as lime, soda ash, or caustic soda to a water to increase its pH value and thus decrease corrosion, in many instances resulted in serious scale formation due to reaction of the alkaline chemicals with the calcium hardness present in the water. On first thought, it may appear that the answer to both classes of problems is so-called "controlled scale deposition," but this is not the case. In the first place, a film or coating, to be fully protective to a metal surface, must be integral with it. A coating formed on a metal surface by the deposition of calcium carbonate scale cannot possibly be integral with it. In the second place, it is practically impossible to control the deposition of a scale so that it is thick enough to prevent corrosion and simultaneously not thick enough to retard heat transfer or cause increased resistance to water flow.

In the Pittsburgh district, the raw water available from the Youghiogheny, Monongahela, Allegheny, and Ohio Rivers is usually of low pH value due to the presence of industrial waste and acid mine drainage. With few exceptions, the problems in this district have been limited to prevention of corrosion. In a few cases, where well waters high in bicarbonate hardness are used, scale deposition on heat absorbing surfaces is a problem. As the effects derived from the flood-control dams become greater, the nature of the problems in this district may change somewhat.

It has been, and still is, the practice in the Pittsburgh district to add lime at the plant intake to reduce the acidity of the river water. The degree of liming in most cases is based on past plant experience and not on the maintenance of a definite pH value in the plant service water. The control of the liming operation is based on a test for residual acidity in the service water. This test is made by titrating a sample of the water with standard alkali, using either methyl orange or phenolphthalein as the indicator. The degree of residual acidity is usually reported in grains per gallon or parts per million sulphuric acid (H_2SO_4), but with no mention of the indicator used in making the test. For this reason, it is difficult to compare the results of one plant with those of another unless the indicator is specified. Some plants "lime down" to 0.5 gr. per gal., others to 2.0 gr. per gal. In the first case, methyl orange is used as indicator while in the second case phenolphthalein is used. In all probability, the pH value of the water in both cases is practically the same for the reason that, with the treatment used, the plant service lines are protected satisfactorily. The use of titration methods for control of lime treatment does not give results that are truly indicative of the condition that it is desired to maintain. These methods give results in terms of alkali-consuming capacity of the water with reference to an indicator rather than indicate the true corrosion potential, which is the pH value.

Since the raw water in the Pittsburgh district is usually free from bicarbonate hardness, the addition of lime for corrosion control does not result in any serious scale deposition.

In the Lake districts and other districts where the raw water contains appreciable bicarbonate hardness, scale deposition is the main problem. Usually, the plant service lines and equipment are so thoroughly coated

with scale that serious corrosion does not occur. However, periodic cleaning is required to keep the lines open and prevent damage to heat absorbing surfaces. Since it would be too espensive to use softened water for general plant use, some degree of relief is obtained in these districts by installing spray ponds or cooling towers in conjunction with condensers and other types of heat exchange equipment and using softened water for makeup. The use of lime-soda softened water as makeup in a spray pond or cooling tower does not give complete freedom from scale deposition for the reason that some calcium carbonate scale continues to form. However, the rate of scale formation is considerably slower than would be the case if raw water, in place of lime-soda treated water, were used for makeup. Zeolite-softened water, or acid-treated water, is better suited for makeup insofar as prevention of scale deposition is concerned but their use results in aggravated corrosion in the system.

THRESHOLD TREATMENT—A NEW TOOL

During the past three years, considerable research and numerous plant scale tests have been conducted in connection with the application of threshold treatment to industrial water problems. Threshold treatment is the use of relatively small quantities, 0.5–5.0 ppm., of molecularly dehydrated phosphates, such as sodium hexametaphosphate, to stabilize moderate supersaturation with respect to calcium carbonate. The use of threshold amounts of sodium hexametaphosphate in water flowing through pipe lines has also been found to have the desirable effect of minimizing corrosion by forming a protective film or coating integral with the metal to be protected. Threshold treatment with sodium hexametaphosphate is based upon the discovery of Rosenstein[1] that a concentration of a molecularly dehydrated phosphate of the order of 1 ppm. would effectively inhibit the formation of calcium carbonate scale when ammonia is added to irrigation waters. The descriptive name, threshold treatment, has been chosen to cover the general process of preventing deposition of calcium carbonate by this means because, apparently, the molecularly dehydrated phosphate acts to remove crystal nuclei from contact with the solution on the threshold of the crystallization process; that is, even before the nuclei reached dimensions great enough to exhibit the properties of the colloid state. Municipal water works have quite widely accepted threshold treatment for preventing incrustation of filters and water mains, and for preventing corrosion in the form of either tuberculation or red water in the distribution system.

Figures 1[2], 2[2], 3[3], 4[3], and 5[3] show the effect of threshold amounts of sodium hexametaphosphate in preventing the precipitation of calcium carbonate and the corrosion of steel.

Figure 1 shows the amount of calcium carbonate that can be held in solution by 2-ppm. of sodium hexametaphosphate when waters of varying degrees of bicarbonate hardness are heated at various temperatures for one hour.

Figure 2 shows how much more calcium carbonate can be held in solution in a water treated with 2-ppm.

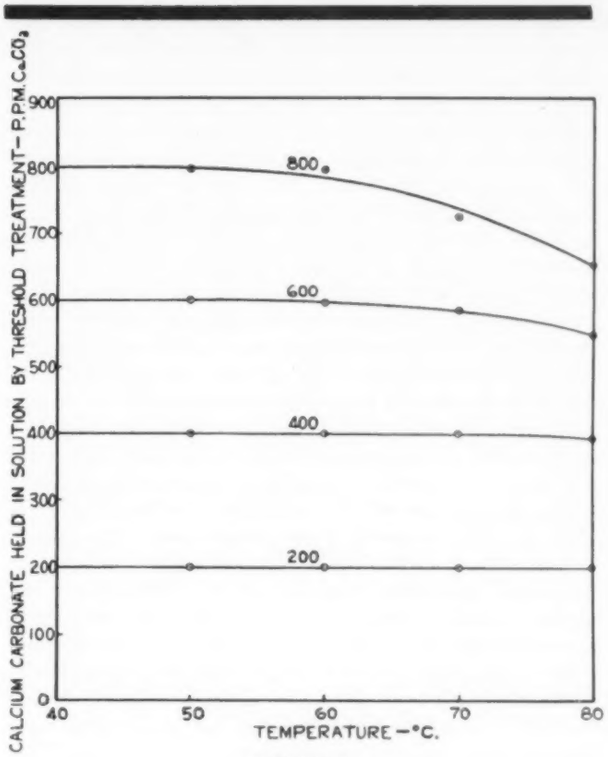


FIGURE 1

of sodium hexametaphosphate and heated than when the same water not so treated is heated in the same manner. For example, when water containing bicarbonate hardness equivalent to 400-ppm. of calcium carbonate ($CaCO_3$) is heated in the presence of 2-ppm. of sodium hexametaphosphate for one hour at 60 degrees C., no precipitation occurs, while in the absence of the sodium hexametaphosphate 90-ppm. of calcium carbonate will precipitate.

*The drop in oxygen content in passing through steel wool is taken as a measure of corrosion.

FIGURE 2

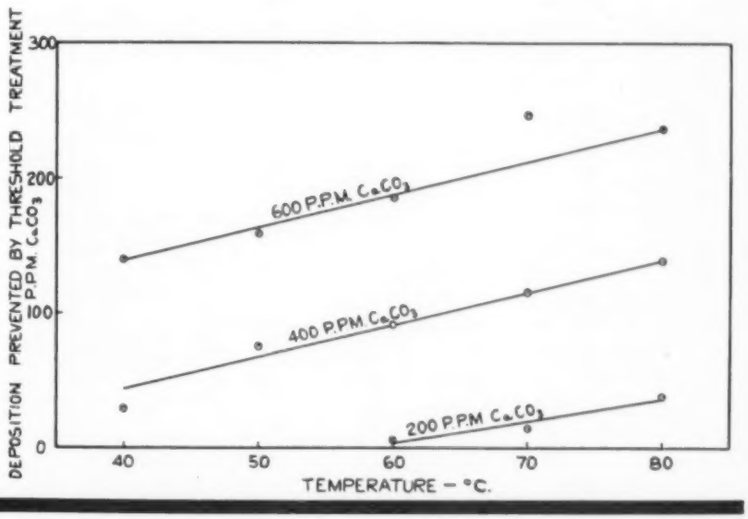


Figure 3* shows the influence of pH upon the decrease in oxygen concentration when adjusted Pittsburgh tap water is passed through steel wool. The curves for the different pH values show two common characteristics; namely, an initial increase followed by a decrease in oxygen drop through the steel wool. At pH values of 4.2, 5.0, and 6.1, the initial increase in oxygen drop is very rapid and indicates that the oxide film is attacked quickly. The curves for pH values of 8.9, 10.0, and 10.4 show the presence of a second factor, one which opposes the effect of the breakdown of the initial film. This opposing factor appears to be the result of the precipitation of the corrosion products very close to the point of corrosive attack. The curves in Figure 3 indicate that the rate of corrosion decreases with increasing pH value; however, increasing the pH value from 6.1 to 10.0 does not aid appreciably in reducing the rate of corrosion. It would appear from these curves that a minimum pH value of 10.4 would be required to accomplish satisfactory reduction of corrosion by this means.

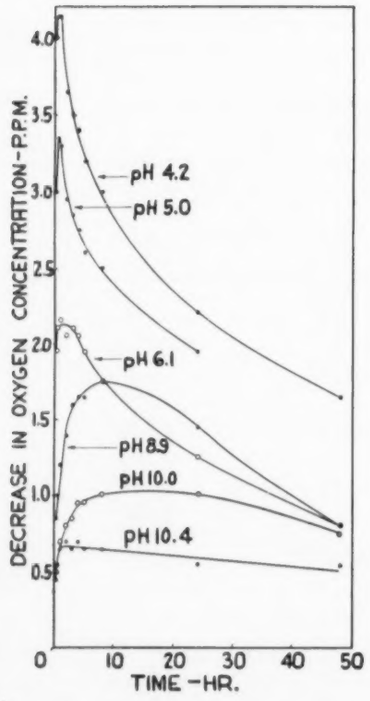
Figure 4 shows the influence of pH upon the decrease in oxygen concentration when adjusted Pittsburgh tap water, containing 2-ppm. of sodium hexametaphosphate, is passed through steel wool. This figure shows that from a pH value of from 6.4 to 10.0, the oxygen drop curves flatten out at the same value within the limits of error of the procedure; also, the maximum protection against corrosion is attained at the same rate from 6.4 to 10.0. In the case of the tests at pH value of 3.9 and 5.0, full development of the protection film has not been attained; however, from the slope of these curves, there is no evidence that they are not approaching the same low final value of the tests made at pH values of 6.4 to 10.0.

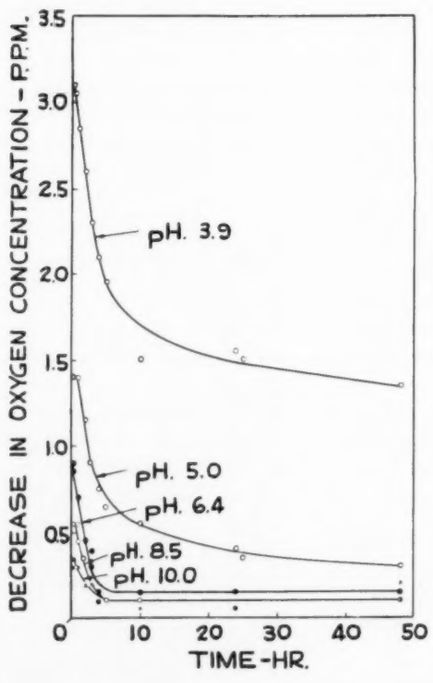
In order to determine whether or not the curves of Figure 4 at the lower pH values actually were approaching the same low final value, tests were conducted in which the protective film was formed by pretreatment at a pH value such that the film could be obtained rapidly and the effect of subsequent lowering of the pH value then determined. Figure 5 shows the results of these tests. The curves of this figure show that the equilibrium oxygen drop attained at the higher pH values can be maintained down to a pH value of 5.2 but not at a pH value of 4.1 or 3.5. This indicates that the curve for pH value of 5 in Figure 3 was probably approaching the same low final value as that obtained at the higher pH values but that the curve for pH 3.9 was not.

It may be concluded from the curves given in Figures 3 to 5, inclusive, that the corrosion rate of a steel surface protected by sodium hexametaphosphate is essentially constant between pH values of 5.2 and 10.0, but that at lower pH values the rate increases.

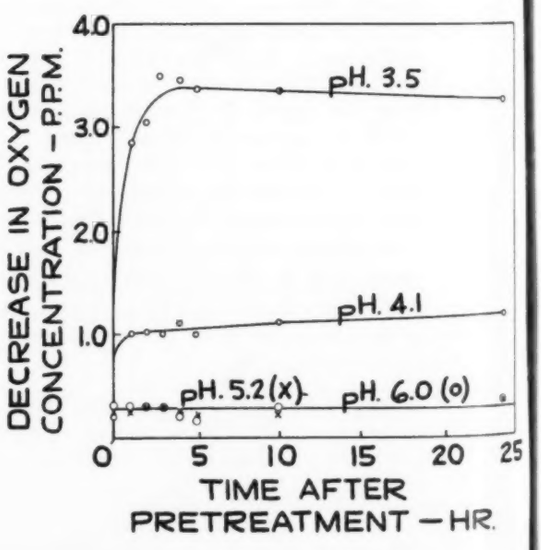
THRESHOLD TREATMENT FOR STEEL PLANT WATER SUPPLY

In cases where the raw river water has low pH value, due to the presence of industrial waste and acid mine drainage, it is necessary to treat the water at the plant intake to protect the water distribution system from corrosion. As noted above, usually this treatment consists of adding lime to the water to reduce the acidity





FIGURES 3 (left) 4 (center) 5 (below)



to a point which has been found by long plant experience to give satisfactory results. Lime is the least expensive chemical per pound that can be used for this purpose; however, if the number of pounds of lime required per million pounds of water is high, the cost of treatment will likewise be high. Sodium hexametaphosphate, on the other hand, is an expensive chemical in price per pound, costing in the neighborhood of fifteen to twenty times that of lime. However, only 2-ppm. of sodium hexametaphosphate are required to retard corrosion in the plant distribution system, so that if it requires more than 30–40 ppm. of lime to treat the plant service water, sodium hexametaphosphate may be used with a resultant saving in treatment cost.

Another saving which results from using threshold treatment instead of lime treatment for the general plant service water is in the cost of equipment for adding the treatment to the water. There are two methods commonly used for adding lime treatment; one method is to use a dry lime feeder at the plant intake. This requires the use of hydrated lime, which is more expensive per pound of available calcium oxide (CaO) than live lime. Some plants have tried this method of adding the lime but found objections to it and replaced the dry lime feeder with a wet treating system. In the wet treating system, live lime is first slaked. The lime suspension is then pumped into a relatively large tank equipped with agitators and is then added to the intake water either by gravity or by means of a pump.

In some of the larger plants in the Pittsburgh district, the daily requirement of plant service water is in the neighborhood of fifty million to one hundred million gallons per day. For this size of plant, the lime requirement per day, when the acidity of the river water is in the neighborhood of 5 gr. per gal., will be 25,000–50,000 lb. To handle this quantity of lime requires relatively large slaking and feeding tanks.

If threshold treatment were used for corrosion control at the rate of 2 lb. per 1,000,000 lb. of water, or 16.6 lb. per 1,000,000 gallons of water, the daily chemical requirement of sodium hexametaphosphate would be 830–1660 lb. To handle this amount of chemical would require a tank of 500 to 1000 gallon capacity, equipped with a dissolving basket. Once the metaphosphate were dissolved and thoroughly mixed, no further agitation would be required for the reason that a true solution would be formed and there would be no settling out as in the case of a milk of lime mixture.

In the coke plant, there are a number of heat exchangers requiring cooling water. If the water used for cooling contains little or no bicarbonate hardness, the amount of scale deposition would be negligible; however, unless the equipment is made of stainless steel, copper, bronze, or similar material, corrosion is likely to occur. If the water contains appreciable bicarbonate hardness, serious scale deposits will occur which will interfere with heat transfer. The application of threshold treatment, either in the general plant service water or ahead of the heat exchangers, will prevent scale deposition and minimize corrosion of the equipment.

Scale formation in ammonia scrubbers is a serious problem in plants where the water used is high in bicarbonate hardness. The ammonia gas (NH_3) dissolves in water to form ammonium hydroxide (NH_4OH), which subsequently reacts with the calcium bicarbonate hardness to deposit calcium carbonate on the scrubber baffles and grids, making it necessary to periodically remove the scrubbers from service for cleaning. Threshold treatment has been successfully used in several plants to remove old scale and to prevent the formation of new deposits in ammonia scrubbers.

The water cooled jackets of blast furnaces, bessemer convertors, electric furnaces, open hearth furnace doors, and frames are subject to either scale formation, corrosion, or both, depending upon the type of water used for cooling. If a non-bicarbonate water is used, corrosion is the problem. If a bicarbonate water is used, scale and possibly corrosion are the problems. A steel plant in western Ohio has had serious difficulty due to failure of open hearth furnace doors and frames. At this plant, cooling water is recirculated through a cooling tower and the makeup water used is a high bicarbonate well water pretreated in a cold batch type softener operating at approximately 75 degrees F., which reduces the hardness to about 1.0–1.5 gr. per gal. Prior to threshold treatment, scale formed on the furnace doors and subsequently cracked off, falling to the bottom of the doors and frame legs and interfering with the cooling water circulation. This caused the doors to overheat and fail. Analysis of the scale showed it to be largely calcium carbonate and iron oxide. Part of the iron oxide resulted from corrosion due to the dissolved oxygen present in the water, but the greater part was due to the doors becoming steam locked, resulting in overheating and causing direct action of the steam and the metal at the high temperatures which obtained. Since using threshold treatment, calcium carbonate scale has been prevented, cracked off scale no longer blocks off the water circulation through the doors, and as a result they are kept cool, thereby preventing direct action of steam with the metal. In this plant, the same water is also used for cooling the slab heating furnace skid pipes and, for the high pressure spray nozzles, where water is used to knock scale off the slabs. Prior to using threshold treatment, the skid pipes became scaled, causing them to overheat and fail. The spray nozzles became plugged, necessitating frequent cleaning. With threshold treatment in use, there is practically no maintenance on this equipment.

In the Chicago district, threshold treatment has been successfully used in the deoxidizing gas cooling water. By preventing scale formation, it has been possible to carry the gas temperature very close to the temperature of the cooling water. This is quite important since they desire, if possible, to maintain the gas temperature as low as 70 degrees F. At times, the cooling water temperature reaches 73 degrees F., so that the nearer the gas temperature can approach the cooling water temperature, the better the operation.

The examples given represent only a few of the possible applications of threshold treatment to the water used in the iron and steel industry. Wherever water contacts iron or steel surfaces, there are potential problems of scale formation or corrosion. From the data available on similar problems, threshold treatment appears as a likely solution to most of them.

---

[1]Rosenstein, L.—U. S. Pat. Re. 20,754, June 7, 1938.
[2]Rice, Owen and Hatch, G. B. J.—Amer. Water Works Assn., 31, 1171 (1939).
[3]Hatch, G. B. and Rice, Owen—Ind. Eng. Chem. 32, 1572 (1940)

DISCUSSION

PRESENTED BY

K. M. PATTERSON, *Manager,* Motor Section, Transportation and Generator Division, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania.

E. W. TREXLER, *Superintendent,* Mechanical Department, Bethlehem Steel Company, Johnstown, Pennsylvania.

W. T. CASE, *Engineer,* A. M. Byers Company, Ambridge, Pennsylvania.

I. F. COFFIN, *Superintendent,* Mechanical Department, Bethlehem Steel Company, Sparrows Point, Maryland.

E. W. BUTZLER, *Sales Engineer,* Hagan Corporation, Pittsburgh, Pennsylvania.

H. H. SHAKELY, *General Master Mechanic,* Hot and Cold Strip Mills, Jones and Laughlin Steel Corporation, Pittsburgh, Pennsylvania.

L. N. McDONALD, JR., *Chief Power and Fuel Engineer,* Carnegie-Illinois Steel Corporation, Youngstown, Ohio.

HARRY FINIK, *Superintendent,* 96 in. Hot Strip Mill, Jones and Laughlin Steel Corporation, Pittsburgh, Pennsylvania.

W. P. HILL, *Steam Engineer,* Bethlehem Steel Company, Sparrows Point, Maryland.

ISAAC HARTER, JR., *Plant Engineer,* Babcock and Wilcox Tube Company, Beaver Falls, Pennsylvania.

H. M. GRAHAM, *Engineer,* Dravo Corporation, Pittsburgh, Pennsylvania.

K. M. PATTERSON: Pumps of one kind or another use thousands of electric motors every year. The application of motors to pumps is less difficult than for some drives such as rolling mills, shears and hoists; however, consideration should be given to the available types of motors and their operating characteristics in order to select the most economical drive.

A centrifugal pump requires low starting torque, 15 to 25 per cent is usually ample. The pump torque increases as the square of the speed and the horsepower as the cube of the speed. The speed torque characteristics of general purpose squirrel cage motors and of standard synchronous motors are equally well suited for centrifugal pump drive.

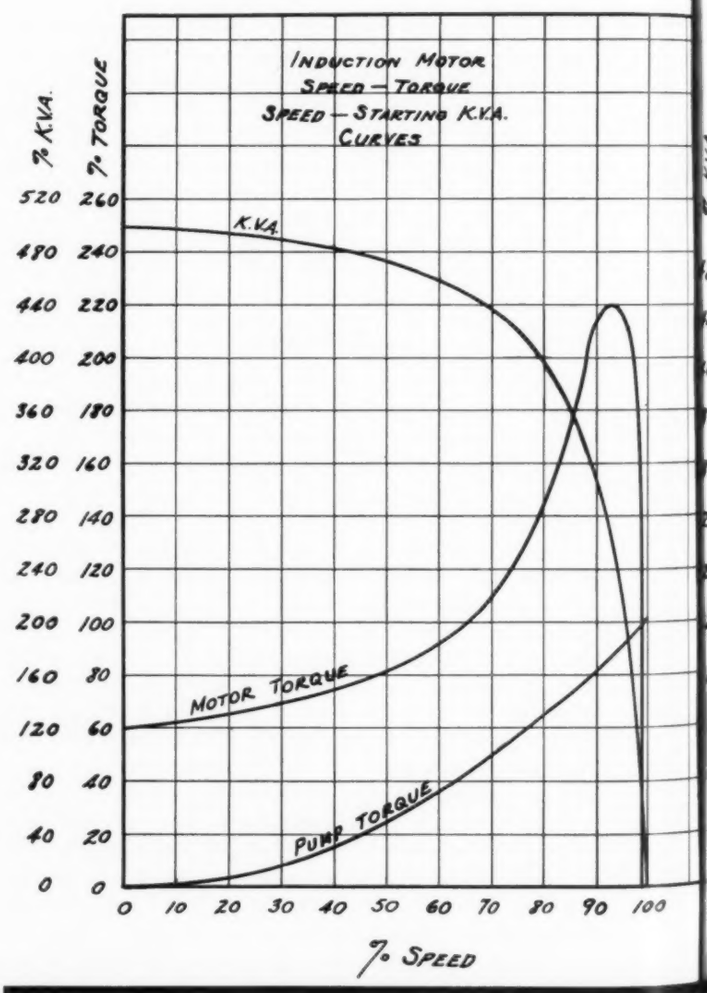
Figure 1 shows the speed torque characteristics of a squirrel cage induction motor. The starting torque is 60 per cent; the maximum torque 225 per cent at 93 per cent speed. The motor will develop full load torque at about 1½ per cent slip and starting across the line the motor will require about 500 per cent full load current.

A synchronous motor starts as a squirrel cage induction motor. Figure 2 shows the starting characteristics of a synchronous motor having 60 per cent starting torque and a pull in torque of 100 per cent. The pull-in torque of a synchronous motor is the maximum constant torque against which the motor will synchronize its connected inertia load when the field is excited. The WR^2 of a pump is not high and the motor may be excited at about 95 per cent speed, hence the motor will have to develop 100 per cent torque on its starting winding at 95 per cent speed, and is said to have 100 per cent pull-in torque.

Reciprocating pumps are sometimes used for high head applications. With this type of pump the torque is constant and the horsepower varies directly with the speed. In larger sizes, these pumps are started unloaded, usually by means of bypasses. The speeds are low compared with centrifugal pumps even when the driving motors are geared. The starting torque required when the pumps are by passed is from 60 to 75 per cent, and for synchronous motors the pull in torque is 40 to 50 per cent. A synchronous motor designed for 40 to 50 per cent pull-in torque will have a somewhat lower starting current than a motor designed for 100 per cent pull-in torque.

Now, which type of motor should be selected for a pump drive? The answer, of course, is the motor that costs less considering first cost, efficiency, power factor and starting performance.

Figure 1—Curves showing speed and torque characteristics of a squirrel cage induction motor.

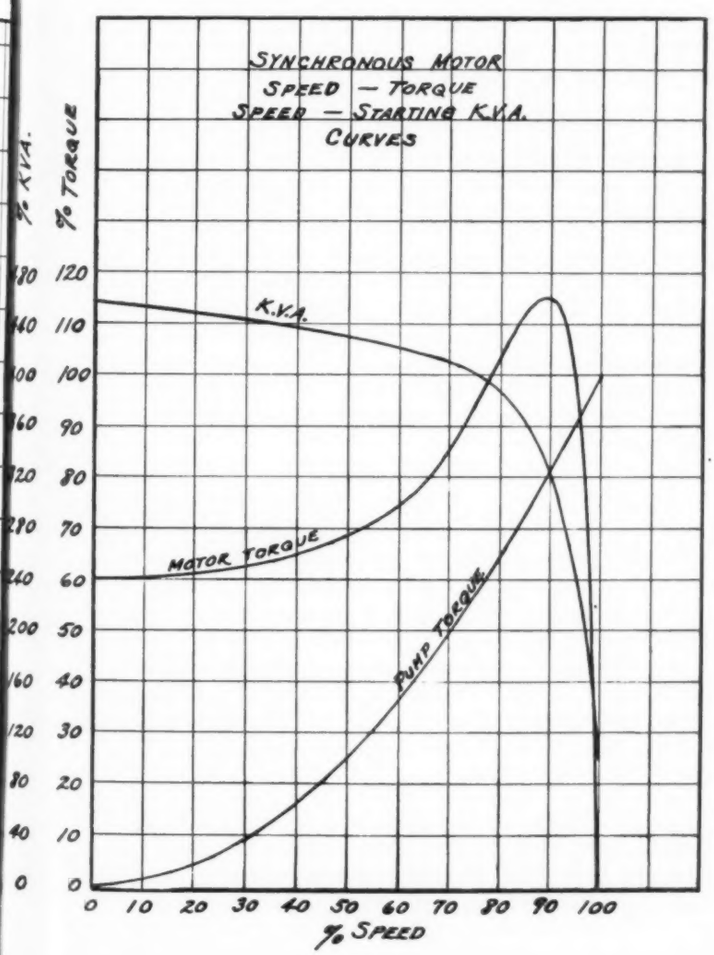


For pumps requiring motors up to 200 hp., the induction motor will always cost less than synchronous motors. Pumps requiring 3600 rpm. motors and 1800 rpm. motors can be more economically driven by induction motors in sizes up to 2000 hp. At 1200 rpm., the induction motor costs less, 350 hp. and below, and synchronous motors less, 400 hp. and above. At 900 rpm., this division point is at about 300 hp. and at 600 rpm., synchronous motors are in general less expensive above 200 hp. As the horsepower increases and as the speed becomes lower the synchronous motor gains the advantage in first cost.

Where the cost of power is relatively high, credit for higher efficiencies may be given to the synchronous motor. At 1800 rpm., the synchronous motor averages 1 per cent better than induction motors, and at 400 rpm. the difference may be 2½ per cent in favor of the synchronous motor.

When pumps are driven from feeders where the power factor is low or where feeders are loaded and voltage regulation poor, credit may be given the synchronous motor for its ability to correct power factor. 80 per cent leading power factor motors cost about 20 per cent more than 100 per cent power factor synchronous motors. The 80 per cent power factor motor will deliver to the line, leading reactive kva. equal to 60 per cent of its full load kva. rating. Where a suitable application exists on a line for the installation of a synchronous motor, its use is the cheapest way to obtain power factor correction. The power factor of an 1800 or 1200 rpm. induction motor may be 95 per cent lagging but at 500 rpm. and lower, its power factor may be less than 80 per cent lagging.

Figure 2—Curves showing speed and torque characteristics of a synchronous motor.



From the standpoint of simplicity in control, full voltage starting is always desirable. When limited power supply or feeder capacity requires limiting the starting kva., motors for pump drive may be designed for reduced voltage starting. Series reactors or resistance, or auto transformers are commonly used for obtaining reduced voltage. Also, motors may be designed for lower than normal inrush when starting on full voltage. This is more difficult to accomplish on induction motors than on synchronous motors because on induction motors changes in design to reduce starting current will generally increase the slip and lower the efficiency, and increase the reactance and lower the power factor. These changes which adversely affect the motor performance may be partly compensated for in an induction motor by reducing the length of the air gap.

Here again the synchronous motor has the advantage. The damper or cage winding on the rotor of the synchronous motor is used only for starting and wide variations in its characteristics may be made to affect only the starting performance of the motor. Considerable range in starting kva. and torque may be obtained by changes in the damper winding design without affecting the running performance of the motor, since it runs in synchronism with the line at no slip and is separately excited with direct current.

A comparison of the cost and the characteristics of synchronous and induction motors would indicate that induction motors are to be preferred for pump drives if the rating is 200 hp. or less and if the speed of the pump is 3600 rpm.

For ratings above 200 hp. in size and for speeds 1800 rpm. and lower, consideration should be given to both synchronous and induction motors.

In favor of the synchronous motor, we should note that the efficiency is 1 to 2½ per cent above the induction motor, and that the power factor is unity or leading for synchronous motors compared with lagging for induction motors. The synchronous motor also offers low starting kva. on full voltage without sacrificing electrical performance (efficiency and power factor) and mechanical considerations (air gap). Against the synchronous motor, we have the fact that a source of excitation is required, which may be supplied from a direct current bus or direct connected exciter. Also, some method of field control is required for the synchronous motor in addition to the line switch. This field application control is available in the form of automatic relays.

E. W. Trexler: I do not have any particular discussion to make on the papers, except that at Johnstown our water supply comes by gravity to the plant from river dams and reservoirs. The question as to the

difference in cost between a gravity supply and a pumping system supply is an interesting one. Maintenance, taxes, and interest on investment on dams and pipe lines largely offset the saving in pumping cost.

The question of gravity supply has not been mentioned in any of the papers presented this evening, and while it is largely a matter of location and topography of country which system is used, it is well to keep in mind that gravity supply usually results in cleaner and colder water wherever this type of supply is possible.

W. T. CASE: There is one point on which I would like to ask a question. The authors discussed quite fully the necessity of filtering water, but I would like to ask what treatment or how much cleaning is required for composition bearings?

C. J. WYROUGH: For composition bearings at our plants the only treatment is from screens and strainers. All inlet water, of course, is limed to neutralize acidity.

W. T. CASE: What size of openings are used in straining?

C. J. WYROUGH: We use screens having ¼ in. holes and strainers having 1/16–¼ in. holes.

W. T. CASE: We use strainers having $\frac{3}{32}$ in. holes.

L. F. COFFIN: The situation at Sparrows Point concerning water supply is entirely different from that of the Pittsburgh district because the bulk of our water is pumped from the Chesapeake Bay which is a tidal body and contains considerable quantity of salt. This water is used in coke ovens, blast furnaces, open hearth furnaces and blooming mill for cooling. We have not been able to use this water successfully on composition bearings. Our finishing mills, such as plate, rod, pipe, hot and cold strip mills, where the maintenance of good surface of rolls is required, use recirculated artesian well water. The subject of premanency and quality of the artesian well supply along the entire Atlantic seaboard is a very serious one at present.

I would like to ask the authors of this symposium whether they have determined definitely at what point the pH value of the water has an injurious effect on the surface of rolls used for rolling highly finished product. Do any of the Pittsburgh river sources or artesian well supplies contain sodium chrloride in any quantity, say in the neighborhood of 10 grains per gal.? In cold strip mills using straight palm oil, has there been any attempt made to reclaim the water wasted from the mills? Do you consider the water temperature of 95 degrees entering the rolls of hot strip mills and rod mills as satisfactory? Do you have any information as to whether the use of high pressure water on rolls without increasing the quantity of water used, has any beneficial effect?

E. W. BUTZLER: I believe that control of the pH value alone will not prevent corrosion of the surface of rolls. It is logical to expect that the lower the pH value of the water, the higher the rate of corrosion. While we do not have test data showing the effect of threshold treatment on preventing corrosion of rolls, it is possible that the coating formed by this treatment may minimize corrosion of the roll surface.

None of the Pittsburgh rivers furnish water having a sodium chloride concentration in the neighborhood of 10 grains per gal. In general, the well waters of this district will not have a sodium chloride concentration greater than 3 or 4 grains per gal. A few wells will approach the 10 grains per gal. figure, but these are not used by the steel mills.

H. H. SHAKELY: Attempts have been made to reclaim the palm oil, but not the water from tandem cold mills.

We run into quite a bit of trouble with high temperature water in the summer time, but not as high as 95 degrees. We do get as high as 90 degrees on hot strip in the finishing train. In the rolling mills, it is not so bad. We would much rather have a temperature of below 80 degrees.

L. N. MCDONALD: We have temperatures at times running as high as 112 or 115 degrees F., but have not experienced any appreciable amount of trouble directly traceable to the high temperature of roll-cooling water.

HARRY FINIK: High temperature water has given us quite a lot of trouble, especially in the summer time.

C. L. MCGRANAHAN: What is the effect on rolls and product?

HARRY FINIK: Hot water does not have the proper cooling effect on work rolls, which shortens the life of these rolls from 300 to 400 tons per grinding. When the rolls "burn up" this way, the product suffers from an "orange peel" surface.

L. F. COFFIN: What do you call high temperature?

HARRY FINIK: I would say 90 degrees. We have that temperature quite frequently in the summer time.

L. N. MCDONALD: At the McDonald strip mill we have had trouble in the past from insufficient cooling of work rolls but have no good reason to feel that it was caused by high temperature water. It appears that troubles with high temperature cooling water are frequently associated with temporary reductions in quantity and pressure of the water supply and that the latter are the primary source of trouble rather than the high temperature.

Where the temperature rise of cooling water is as low as in roll cooling and where the boiling point is not approached, I believe that the difference in cooling effect of a given quantity of water applied in the same way at the same pressure with water of say 80 degrees F. as compared to water at 115 degrees is trivial. In neither case is the roll surface cooled to a temperature even approaching the temperature of the coolant and the effect of the cooler water on heat transfer is necessarily small since the temperature differential between roll and cooling medium is only nominally increased by the use of cooler water.

H. H. SHAKELY: I am not able to give exact figures, but we tried increasing the water pressure on a 54 in. tandem mill on tin plate. We started with ½ in. nozzle and it was impossible to run at high speed because we could not maintain temperature on the rolls. We increased the pressure from approximately 22 lb. to 60 lb. and we found we were able to get to maximum

rolling speed, which I believe is 1750 ft. per min. We now have plenty of cooling on this mill. There is a definite benefit from using high pressure water as shown by this experiment. We have also been able to reduce the quantity of water by reducing the size of the nozzle from ¾ and ½ in. to ⅜ in.

W. P. HILL: In connection with the use of sodium metaphosphate will the use of two parts per million to start with be enough, or do you have to use 10 parts per million or more?

E. W. BUTZLER: In starting threshold treatment it is desirable but not absolutely necessary to use concentrations of sodium hexametaphosphate in excess of 2 parts per million in order to hasten the formation of the initial protective coating. Two parts per million will form the coating but it will require more time.

ISAAC HARTER, JR.: I can understand why it is necessary to protect pumps from foreign substances, but nothing has been said about reservoirs or settling basins instead of filters.

H. M. GRAHAM: In general, the quantities of water pumped in the usual steel mill are so great that very large storage reservoirs would be necessary if attempts were made to settle the water before using it. As steel mills are invariably crowded for space, there is not room for such reservoirs. The result is that the small standpipe has been pretty generally used.

TENTATIVE LIST

Papers to be read at 1941 Convention

Motor Application and Power Requirements for Strip Processing Lines

Temper Mill Drives and Control

Transmitting Torque from Electric Motors

Ore Bridges

Report on Field Tests on IR Drop Compensation

Report of Crane Specifications Committee

Relation of Raw Materials to the Manufacturing Processes

Effects of Rates of Operation in the Coke Plant

Modern Sintering Plant Design and Construction

Scarfing Processes for Special Steels

Modern Plate Mill Design

Special Oxy-Acetylene Applications in the Steel Plant

Electrolytic Tinplating

Design and Operation of Bessemer Converters

Roll Reclamation

Rolling Pressures in the Strip Mill

Classification of Modern Welding Equipment

Welding in Cold Strip Processing

Advance Methods of Welding

Modernization of Heating Furnaces

Fuel Applications in Metallurgical Furnaces

Organization of Fuel Department Personnel and Practice

Modern Designs of Annealing Covers

Immersion Heating for Pickling Baths

Combustion Control for Combination Firing

Sealing Methods for Oil Film Bearings

Diesel Engine Lubrication

Filtration and Reclamation of Oils

Association Headquarters
STATLER HOTEL

Technical Sessions and Exposition
CLEVELAND PUBLIC AUDITORIUM

SEPTEMBER 23-24-25, 1941

ADVERTISING PAGES REMOVED

"If anyone is skeptical about the value of BUSS Time-Lag..Tell him how we wiped out shutdowns on our elevators—

• • • • SO SAYS CHIEF ENGINEER, E. LEISSE, POTTSVILLE HOSPITAL, POTTSVILLE, PA.

ALL RIGHT, PLANT MEN, *Here's How—*

In the words of Mr. Leisse, "The fuses protecting the 11 h. p. 220 volt motors on our elevators used to give us a lot of trouble—blowing on an average of once a week. The blows were caused by the operators inching the car in order to level it.

"Unfortunately for us we had not paid much attention to the claims made by BUSS fuses in the way of eliminating such shutdowns—but about 9 months ago, we decided to give them a trial. Now we wish we had tried them long before, because we have not had a fuse blow on the elevator circuit since we installed them.

"If anyone is skeptical about the value of BUSS Time-Lag you can tell him how we wiped out these shutdowns on our elevators that used to cause us so much grief."

ARE YOU TOLERATING USELESS SHUTDOWNS THAT INTERFERE WITH PLANT OPERATION?

Sometimes executives in charge of plant operation or maintenance think that there isn't much they can do about protective devices opening needlessly. Such men however have probably not investigated BUSS Super-Lag fuses.

BUSS fuses are built upon the principle that protective devices should be made to protect—but not open needlessly.

Time-Lag Helps Prevent Shutdowns

Witness the Super-Lag development which gives BUSS Fuses a time-lag sufficiently long to permit them to hold when harmless overloads occur. Hence when two or more motors start simultaneously or apparatus jam momentarily or operators feed machines excessively BUSS fuses will generally hold and keep the circuit alive—instead of blowing and causing a shutdown that is useless and unnecessary.

Fuse-Case Design Helps Prevent Shutdowns

Time-lag is only part of the story in BUSS fuses. Poor contact is also a frequent cause of protective devices opening needlessly. Hence the BUSS Fuse-Case has been designed to prevent any chance of poor contact developing within the fuse. The simple correctness of BUSS design guarantees good contact when the fuse is renewed and that this good contact will be maintained no matter how long the fuse is in service.

HOW TO GET QUICK ACTION IN YOUR PLANT

Pass the word along that in order to help eliminate shutdowns that interfere with operations all fuses installed should be BUSS Super-Lag fuses. Also seeing to it that all purchase and stock records are changed will assure you continuation of the trouble-free service that only BUSS fuses can give.

BUSSMANN MFG. CO. • ST. LOUIS, MO.
Division McGraw Electric Company

BUSS Super Lag

NEW LITERATURE . . .

▲ A new book on welding instruction, entitled "Lessons in Arc Welding," published by the Lincoln Electric Company, Cleveland, Ohio, should prove an aid in the training of defense workers. It is 176 pages, 6 x 9 in.; 170 illustrations, including photos and drawings; and is bound in semi-flexible simulated leather, gold embossed; the price is 50 cents per copy, postpaid anywhere in U.S.A., 75 cents elsewhere.

This book makes available to industry and to engineering colleges and universities, also trade and vocational schools, the accumulated welding instruction information from the Lincoln Welding School, which has been in continuous operation for 24 years. It has become, in its early edition, the standard text book of educational institutions throughout the country which now include courses in arc welding as a regular part of the curriculum.

Helpful to beginners learning to arc weld, also to experienced welders desiring its comprehensive practical information, and to welding officials, such as supervisors, foremen and instructors, as well as others interested in the subject, the book comprises a ready reference on arc welding and a guide to its proper application. It will be found invaluable, at this time, to any industrial organization faced with the necessity of training its own welders to meet demands imposed by the national defense program.

"Lessons in Arc Welding" is a series of 60 lessons which present, in concise manner, fundamental facts of welding, knowledge of which will enable the welder to utilize the process successfully and economically.

Beginning with an introduction giving preliminary instruction to the welder, including suggestions for making and following a definite plan for learning the fundamental principles of arc welding, examining welds, etc., the lessons cover the theory and practice of electric arc welding in a comprehensive manner. Text explanations are graphically supplemented by by-line drawings and photos for ready understanding.

A valuable feature of the book is the set of questions and answers for each lesson enabling the student to check his knowledge. Since the questions are headed by the lesson number and subject matter, they can be of assistance in furnishing the solution to problems. Knowing the subject matter, the student can refer to the index, find the lesson in which it is covered, then turn to the questions on that particular lesson in the back of the book.

"Lessons in Arc Welding" may be obtained directly from the Lincoln Electric Company, or through any of its branch plants, dealers or representatives, or through any recognized book dealer.

▲ In order to inform the American people of the activities of The Timken Roller Bearing Company in connection with the defense program, the company has published a 32 page booklet, "The Vital Importance of Timken Bearings in Defense." Profusely illustrated and attractively presented, the publication shows the vital part played by anti-friction bearings in the modern instruments of defense, as well as in the various machines which process and fabricate materials used in the manufacture of such instruments.

Besides showing the vital importance of Timken bearings and steel in the machinery used for making defense equipment and in the defense equipment itself, the book further shows the way in which the Timken Company met the responsibility of increased production by expansion of basic production facilities, fabricating equipment, heat treating capacity, etc. This expansion was started months before the present emergency developed, with the result that most of the new equipment is already in operation.

▲ Allis-Chalmers Manufacturing Company, Milwaukee, Wisconsin, has issued a new bulletin, No. B-6104, on Multi-Stage Turbo-Blowers, such as used in handling air or gas for diverse applications like blast furnaces and convertor blowing, gas boosting and exhausting, agitating and aerating, circulating gases in chemical plants and compressing refrigerants. Its 32 pages of well-illustrated material cover centrifugal type blowers built in standard sizes for inlet volume up to 130,000 cu. ft. per min., and larger, for air pressures up to 35 lb. gauge.

▲ In spite of war conditions, Stahleisen, which is the publishing department of the German Iron and Steel Institute, has undertaken the publication, in German, of an extended series of comparatively small books on well circumscribed subjects.

The first, on steel wire, has just been received. Entitled Steel Wire (Stahldraht), by A. Pomp, the book contains 275 pages, 6¼ x 9 in., 265 illustrations and 18 tables.

Dixon's Solid Belt Dressing makes belts grip better *and* last longer. Just hold the big 2"x8" bar against the *running* belt. Peel off cardboard wrapper as dressing is used. Perfect for leather, rubber and composition belts. Buy from your usual supplier or write Dept O-18.

SINCE 1827

AND WHAT A BIG HELP THESE ARE

GRAPH-AIR GUNS
DRY GRAPHITE LUBRICATION FOR LOCKS AND A 1000 OTHER USES—SQUEEZE 'EM
DIXON'S PIPE JOINT COMPOUND
DIXON'S GRAPHITE SEAL
DIXON'S CUP GREASE
DIXON'S FLAKE GRAPHITE

JOSEPH DIXON CRUCIBLE CO.
JERSEY CITY, NEW JERSEY

326

ADVERTISING PAGES REMOVED

DESIGNED AND BUILT BY **UNITED**

NEW IRON ORE MINE TO HAVE MODERN BUILDINGS

▲ Construction was started May 1st on a modern $250,000 layout providing ground facilities for the new iron ore mine now being developed two miles northeast of Ishpeming, Michigan, by the Negaunee Mine Company, which is owned jointly by the Cleveland-Cliffs Iron Company and the Bethlehem Steel Corporation. Contracts for design and construction of the building have been awarded to the Austin Company.

The development has been planned to provide the most complete facilities obtainable for the convenience of miners and to meet all the mechanical needs of the mine, which will have an ultimate capacity of 1,600,000 tons per annum. Four main buildings are included in the interconnecting ground layout which includes a 90 ft. covered passageway to the mine elevator platform, so that men coming up from the mine can reach the dry house where they change clothes without going out-of-doors. This building, 60 ft. by 280 ft., will have a spacious shower room, 35 ft. by 40 ft., and a large battery of toilets completely separating the quarters provided for dirty clothes from the room where men will leave their clean clothes on entering the mine.

The accommodations will be adequate to meet maximum labor requirements on three shifts representing the employment of approximately 1000 men. Salt-glazed tile will be used on wall surfaces throughout the dry house, which will have panels of glass block and will be equipped with a special ventilating system.

An office building, 30 ft. by 80 ft., is to be erected in front of the dry house and will be of modern design with face brick and Indiana limestone trim.

Power machinery required to operate the mine will be housed in a two-story engine house, 60 ft. by 241 ft., extending from the dry house to a special shop wing, 60 ft. by 200 ft. The shop section will include a warehouse, 30 ft. by 100 ft., and special quarters for electricians, machine shop, blacksmith shop, carpenter shop, as well as wash-up, shower and

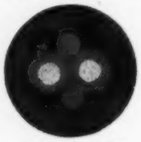
▲ To meet the demand for greater production and faster heating the Bloom Engineering Company is manufacturing a complete line of extra large gas burners, the largest of which weighs 1800 lb. and has a capacity of 70,000 cu. ft. of coke oven gas per hr.

These burners are designed for use with cold or preheated air, and have been applied to many large furnaces such as soaking pits, preheating pits for alloy steels, and gun forging furnaces. The manufacturer claims that preheated air can be handled with the same degree of accuracy and controllability as can cold combustion air, and these claims have been adequately proven by performance. Quality heating has been successfully obtained with preheated combustion air, with an accompanying increase in speed of heating and a decrease in fuel consumption.

Draws its Power Through

OKOCORD ELECTRIC MAGNET CABLE

SPECIFICATIONS
Okocord Electric Magnet Cable for 77" C-H Magnet



No. of Conductors
Two
Size of Conductor
#1 Awg, 427 strands
Conductor Insulation
5/64" Okonite rubber
Fillers
Rubber with cotton binder
Sheath
11/64" Okocord 60% rubber with tire-cord reinforcing
Outside diameter
1.415"

This 77-inch magnet with its tremendous lifting capacity was manufactured by Cutler-Hammer, Inc., Milwaukee, Wis., for Columbia Transportation Company, an affiliate of Oglebay Norton & Company, and is installed on the steamer O.S. McFarland, where it greatly reduces handling time.

As with all magnet cables, flexibility and extraordinary resistance to wear were primary considerations in the design and construction of the Okocord cable, one of the largest flexible cables ever built, through which flows the 230 Volt — 115 ampere power supply for the magnet.

Like all Okocord cables, the 60% Up-River Fine Para rubber jacket, vulcanized under pressure in a continuous metal mold, has a tensile strength of over 3500 lbs. per square inch and forms a rugged, flexible, smooth and snag-proof covering which guarantees long service.

THE OKONITE COMPANY Passaic, New Jersey
Offices in principal cities

OKOCORD OKONITE **RUBBER-SHEATHED PORTABLE CABLES**

locker facilities for the surface crew.

The property will be operated and managed by the Cleveland-Cliffs Iron Company. It is situated midway between the first two mines ever developed on the Marquette range, oldest ore fields in the Lake Superior region. It is 17 miles from the port of Marquette.

The mine shaft is at present being developed to a depth of approximately 3000 ft. and will be deepened as conditions warrant. Ore will be hoisted in two skips having a capacity of 12 tons of ore each, which will be operated in balance. A double deck cage is being provided to transport men to the working areas and will be capable of accommodating 75 men per trip. The steel headframe of the shaft will extend 200 ft. above ground level. This will be equipped with a passenger elevator to take men to the stocking trestle platform and various other points for maintenance work.

NEW LUBRICATING OIL FOR HIGH TEMPERATURE

▲ A lubricating oil which does its work, then vanishes without a trace, is being introduced by the Esso Marketers to industries faced with problems of lubrication at extreme high temperatures. A contradiction in petroleum research which has pointed constantly toward giving lubricants greater endurance and more lasting quality, the new oil, known as Caloria, is the first petroleum lubricant to embody the characteristic of complete disappearance at high temperature. It is designed to solve an old problem of lubrication under intense heat, such as is found in kiln cars, glass making machinery, ceramics and glass molds, annealing and baking ovens, working parts of die casting machines, and various hot parts of machines in the metal industries.

Unlike conventional petroleum lubricants which often begin to break down or crack at 400 degrees F., and thereby leave a residue of carbon, varnish, and other matter which coats bearings and causes wear and power loss, Caloria is recommended only for temperatures above this where it lubricates and while doing so evaporates completely, leaving the lubricated surfaces absolutely clean. Laying up of equipment for cleaning or replacement of bearings is eliminated, replenishment of the lubricant being all that is required to maintain equipment in service. Extensive field tests have proven that this "vanishing oil" is the solution to hot spot lubrication.

The composition of Carolia is a guaraded trade secret for which a patent is being sought. The individual constituents are all petroleum derivatives and are not in themselves lubricants; only when properly combined do the mixtures possess excellent lubricating value. This manufacturing can be done with existing refinery equipment.

The new product is available in several viscosities ranging from a light-bodied water-white liquid to a viscous, slightly turbid liquid which requires more than 11 hr. for two oz. to flow through the orifice of a viscosity measuring device. Different

TRUFLO FANS...

Built Right TO BEAT THE HEAT

TRUFLO CRANE CAB FANS
For cooling interiors of crane cabs and other confined areas. Adjustable both horizontally and vertically. Four blade type, 12 and 18 inch sizes.

Summertime—and HOT weather—are here. Now, when top production rates must be maintained, the comfort of your workmen is an important factor in keeping production at high levels. Truflo Fans lessen worker fatigue by supplying clean, cool air wherever it is needed.

All Truflo Fans are designed and built correctly for utmost in efficiency and economy of operation. Perfectly balanced one-piece aluminum alloy blades assure long motor life and low power costs...extra strong frames stand up longer under hard use... rugged wire guards protect against injuries.

There is a style and size of Truflo Fan for every cooling and ventilating job. Write for free illustrated literature on any of the following types:

TRUFLO PORTABLE COOLING FANS
Easily portable. Help keep efficiency high where work is hottest. 12 to 36 inch diameters.

PORTABLE COOLING FANS ● CRANE CAB FANS ● WALL FANS ● EXHAUST FANS ● BLOWERS ● ROOF VENTILATING FANS ● PENT HOUSE FANS

TRUFLO FAN COMPANY

554 MAIN ST., HARMONY, PA.

viscosities are needed to meet varying methods of lubrication.

In addition to its ability to disappear completely under high heat, Caloria has another unusual characteristic. Conventional oils spread over many hundred times their original area when dropped on a surface heated to 400 degrees F. Caloria spreads to only four or five times its original area, assuring that it will remain in greater quantity and for a longer time on bearing surfaces under high heat.

The amount of time required for all of the Caloria in a bearing to disappear depends upon the amount used, the surface area to be lubricated, the time the oil is in contact with the surface, and the bearing temperature. Replenishing may be regulated accordingly.

For use in cases where Caloria cannot be re-applied before complete evaporation takes place, as in some kiln car bearings, the use of Van Caloria, which incorporates colloidal graphite, will cause a dust thin layer of graphite to remain on the bearings after complete disppearance of the petroleum lubricant. The graphite will prevent metal-to-metal contact until a new supply of Van Caloria reaches the bearings.

GREAT LAKES STEEL TO PRODUCE LIGHT PLATES

▲ A program to provide an annual production of 300,000 net tons of light plates at the Ecorse plant of Great Lakes Steel Corporation, unit of National Steel Corporation, is announced by George R. Fink, president.

The move is being taken to help speed the defense program, Mr. Fink said, and is designed to help overcome the current shortage in light plates which is proving a particular impediment in the construction of railroad cars and ships.

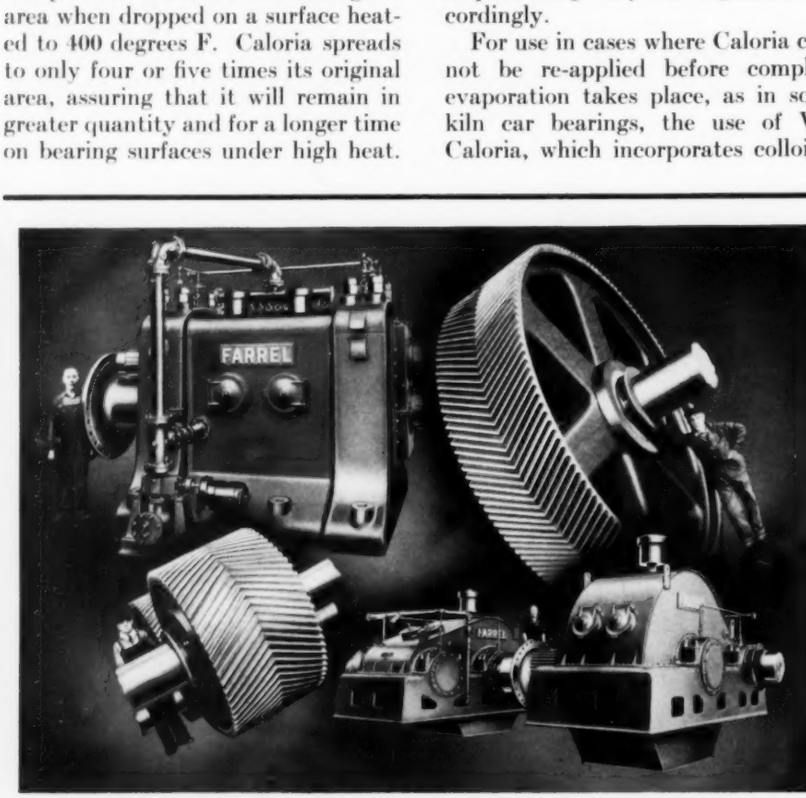
The program will involve changes and additions to the finishing department of the No. 2—96 in. hot strip mill as follows:

The present 96 in. x ½ in. parting shear is to be replaced by a 96 in. x 1 in. parting shear. The piler at the end of the runout table will be increased to permit the piling of plates up to 30 ft. in length. Runout tables, kickoff and cradles for piling plate are to be installed at the end of one of the existing shearing lines.

A new shearing line, consisting of a charging car, lift table, trimmer, leveler, shear, plate kickoff, and piler, with the necessary roller tables between the units, will also be installed. To provide room for the new shearing line it will be necessary to extend the hot strip mill finishing building.

The new facilities will permit the rolling of plates up to 90 in. wide x ⅜ in. thick x 30 ft. long. Actual rolling will be done on the 96 in. hot strip mill, which, although primarily designed for the rolling of strip sheets, will require no alteration. Maximum plate production will utilize approximately one-third of the normal capacity of the mill.

By combining present and new facilities it will be possible to start plate production at the Great Lakes plant within six months, whereas at least 18 months would be required for the construction of an entirely new plate mill.



FARREL GEARS AND DRIVES

for Heavy Loads and High Speeds

Farrel Gears and Gear Drives are known for their rugged endurance and dependable performance in the severe service encountered in the modern steel mill. They are designed and built to withstand the stresses, shocks and wear imposed by heavy loads and high speeds.

Continuous herringbone teeth give Farrel-Sykes Gears the "backbone" for heavy duty service and provide extra strength for greater load-carrying capacity. Precision generation of the teeth by the famous Sykes process makes them exceptionally smooth-running and quiet in operation.

Advanced engineering, carefully selected materials and precision construction of Farrel Gear Drives and Pinion Stands assure efficient, economical, trouble-free operation under the toughest conditions.

Long experience and continuous study of the design, manufacture and application of gearing have given Farrel engineers expert knowledge of all the numerous factors necessary for successful operation. They know the requirements for steel mill drives and their services are at your disposal in connection with gear problems.

FARREL SYKES GEARS

FARREL-BIRMINGHAM COMPANY, Inc.

ANSONIA, CONN. - - - - - BUFFALO, N. Y.

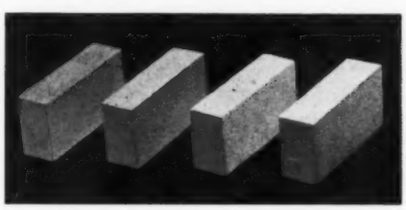
The Gear with a Backbone

OVENS TO BE ADDED TO BY-PRODUCT PLANT

▲ Koppers Company, Engineering and Construction division, has been awarded a contract by the Philadelphia Electric Company to build a battery of 21 coke ovens at its by-product coke plant at Chester, Pennsylvania. The 21 ovens, of the Koppers-Becker underjet type, will have a total coal carbonizing capacity of 142,000 tons a year. Work will be begun immediately, and the ovens are to be completed in April, 1942.

INSULATING FIRE BRICK FOR 1600-2600° SERVICE

▲ A new line of insulating fire brick for the temperature range from 1600 to 2600 degrees F. has just been announced by Johns-Manville, designed for direct exposure in a wide variety of furnaces, ovens and other heated equipment, except where subject to slag action or mechanical abuse. The brick are furnished in four temperature limits: JM-16, for exposed service to 1600 degrees F. and for back-up service to 2000 degrees F.; and JM-20, JM-23, and JM-26 for exposed or



back-up temperatures to 2000, 2300, and 2600 degrees F., respectively. The new line supplements the Johns-Manville Sil-O-Cel series of back-up insulating brick for temperatures of 1600, 2000, and 2500 degrees F.

The new insulating fire brick are produced from a plastic refractory clay and an organic filler which, upon being burnt out during the manufacturing process, gives a uniform, controlled pore structure to each of the various types, and imparts the characteristics of light weight, strength, and high insulating value.

Production of the new brick has been recently started at Zelienople, Pennsylvania, in Johns-Manville's newest plant, which was rushed to completion ahead of schedule to meet the need for such materials in the industrial expansion program for defense.

MOTOR CONTROL CENTER PROVIDES FLEXIBILITY

▲ The Trumbull Electric Manufacturing Company of Plainville, Connecticut, recently announced a new line of Trumbull motor control centers, representing an assorted assembly of Sizes 1, 2 or 3 combination magnetic starter units of standardized width in vertical section troughs, in which power is supplied through bus bars.

These assemblies may be located in one central point, or if complete centralization of all starting units is not feasible, these larger centers may be divided into smaller sections and distributed as is most convenient for the machine layout.

Immediate connection is made between motor control center and load (motors) by simply inserting the starting units, which are equipped with stabs, onto the bus bars in the power trough.

These assemblies provide great

Make sure of **BALANCED**

DRAFT CONDITIONS IN

OPEN HEARTHS
•
SOAKING PITS
•
ANNEALING FURNACES
•
SLAG MILLS

GOOD furnace control requires an accurate record of draft, pressure or differential, as given by Hays Series OT Supersensitive Draft Recorders.

These instruments give a correct indication of furnace atmospheres and a permanent record of pressures and drafts at vital points as guides for most effective operation.

Hays OT Draft Recorders give two draft values, two pressure values, two differential values or a combination of any two of these three values. Built stout enough for Steel Mill service yet sensitive enough to register accurately in increments of .0025 inches water.

Write for complete descriptive literature to 955 Eighth Avenue, Michigan City, Indiana.

The HAYS CORPORATION
SINCE 1901
COMBUSTION INSTRUMENTS AND CONTROL
MICHIGAN CITY, INDIANA, U.S.A

QuelArc circuit breaking plugs and receptacles for heavy portable equipment, 2, 3, 4 wire types, 20 to 200 amperes, 250 volts DC, 600 volts AC. Bulletin 1140-2.

Triploc and Multiple Circuit plugs and receptacles for portable tools, instruments and control circuits. Interchangeable contact units permit any combination, 1 to 32 poles. Bulletin 1140-1.

Example of Multiple Unit plug and receptacle assembly with three 4-pole contact units, total 12 poles.

General purpose plugs and receptacles, for heavy duty portable tools and equipment, 2, 3, 4, 5 poles. Bulletin 1140-3.

LESS MAINTENANCE

—because these plugs and receptacles are built to stand heavy service

Pyle-National plugs and receptacles not only provide for safe and convenient portable electrical connections, and control and instrument circuits, but also help you maintain continuous service. In these times their ability to stay on the job with the minimum of attention is more valuable than ever before. Pyle-National plug and receptacle equipment is built for mill service, with full bakelite insulation, protected contacts, and heavy drawn steel or cast metal housings. QuelArc circuit breaking types have exceptionally long insulating paths through air or across insulating surfaces. Both male and female contacts are enclosed in bakelite insulation. Contacts are individually renewable.

The complete Pyle-National line includes plugs and receptacles for all types of service, in a range of capacities up to 200 amperes. Bulletins with complete listings will be sent upon request.

PYLE-NATIONAL

The Pyle-National Company, *General Offices and Works,* 1334-58 North Kostner Avenue, Chicago, Illinois • *Offices:* New York, Baltimore, Pittsburgh, St. Louis, St. Paul, San Francisco.

CONDUIT FITTINGS • LOCOMOTIVE ELECTRICAL EQUIPMENT • FLOODLIGHT PROJECTORS

flexibility, convertibility and all interior parts are completely accessible from the front.

Illustrated and described in Circular No. 331 sent on request.

RETURN OF REFILLABLE CONTAINERS ESSENTIAL

▲ In the bustle accompanying production efforts entailed by the national defense program, deliveries receive great consideration, but little or no attention is given to the return of containers or packages which may be re-used. The wire and cable manufacturers are faced with an acute shortage of shipping reels, spools, and cases, primarily through the failure of busy industries to return empty containers. This shortage is threatening deliveries on vital defense orders. Wire and cable manufacturers are buying and making containers as fast as possible but new containers are not available in adequate volume for the urgent requirements of defense. More containers are needed quickly—all empty reels, spools and cases scattered throughout the nation must be returned and put to work at once. The objective is double-barrelled: (1) wire and cable shipments to national defense projects will be expedited; and (2) time, materials and labor required to build new containers will be conserved for other defense purposes.

Other branches of manufacturing are similarly affected, and it is essential that every effort be made by the consuming industry to promptly return all re-fillable containers and packages.

CONSTRUCTION BEGINS ON ARMCO TEXAS PLANT

▲ When George M. Verity, chairman of The American Rolling Mill Company, thrust a 31-year-old silver spade into Texas earth in a 600 acre woodland site on the ship canal near Houston on May 27, the open hearth department of the first large steel plant in the Southwest was officially begun. It adds a new basic industry to that region, and adds another strong link to national defense efforts.

Using a process for making steel exclusively from scrap iron developed in 1918 by the Sheffield Steel Corporation which makes possible the operation of steel producing units distant from iron ore mines, the three open hearth furnaces of the Texas unit will produce 200,000 tons of ingots annually. Initial equipment will include billet mills and finishing mills. The finishing departments will have a structural and tie plate mill, a merchant bar mill, reinforcing and rod mills, a wire plant, and hot rolled sheet and plate mills. As the site is of ample size, with about one mile of frontage on the Ship Channel, the plant has been designed to permit of further expansion as demand requires.

Among the types of steel products which will be made are merchant bars and shapes, rods, reinforcing steel, tie plates, structurals, sheets, plates,

10 ton, 65'-0" span Cleveland steel-mill crane.

LOWER COSTS WITH CLEVELAND ALL-WELDED CRANES

Because maintenance of Cleveland all-welded cranes is little more than a periodic lubrication job, their operating costs are very low.

Of greater importance, they are always ready to serve, and lost time, due to lack of crane service, is practically eliminated.

Mill men, who know, are in general agreement that costs are lower with Cleveland all-welded cranes.

THE CLEVELAND CRANE & ENGINEERING CO.
Wickliffe, Ohio

CLEVELAND CRANES
ALL-WELDED OVERHEAD TRAVELING CRANES
Other products: CLEVELAND TRAMRAIL and STEELWELD MACHINERY

ADVERTISING PAGES REMOVED

fence, nails, manufacturers' wire and many other items.

The Sheffield plant in Texas is unique in that it will be the only steel plant in the world built in a forest. Company officials insisted that as many as possible of the venerable oaks and pines which heavily studded the site be retained.

▲ Various port and stop arrangements provided by Multiport valves are presented in a new bulletin issued by Merco Nordstrom Valve Company. Ground plans are shown of the arrangements effected by 3-way, 2-port; 3-way, 3-port and 4-way, 4-port valves at various degrees of turn, 90 degrees, 180 degrees and 270 degrees. Illustrations of the different types of Nordstrom Multiport Valves are shown, with specification tables.

Multiport valves permit quick switching from line to line. One valve can do the work of two, three or four ordinary valves, according to the arrangement of flow-ways and ports and degrees of turn. Sizes range from ½ in. to 16 in., for pressures tested to 3000 lb.

For high temperature services and where extremely corrosive or erosive line contents are handled, the Multiport type may be furnished with Merchrome coating. This coating presents an extremely hard surface which prevents galling and abrasion regardless of line contents or temperature.

The new Bulletin describing Multiport Valves, No. V-135, may be had by addressing Merco Nordstrom Valve Company, 400 Lexington Avenue, Pittsburgh, Pennsylvania.

▲ Republic Steel Corporation, with large and important defense orders on its books, operated at 103.4 per cent of capacity for the month of May, establishing new all-time ingot production records at its Chicago, Cleveland and Massillon open hearth plants.

A new high was also established in the tonnage of electric furnace ingots produced at Canton, making a new total ingot production record for the Central Alloy District.

All previous records were eclipsed on the company's bar mills at Canton, Massillon and Youngstown, at Chicago and at Gadsden, Alabama. Total production of bars for the corporation as a whole likewise established a new high.

Every plant in Republic's Union Drawn Steel Division hit new production highs. Three plants of the Steel and Tubes Division also established new highs for a single month's output.

Altogether a total of 50 Republic mines, mills and furnaces participated in the new records made for May.

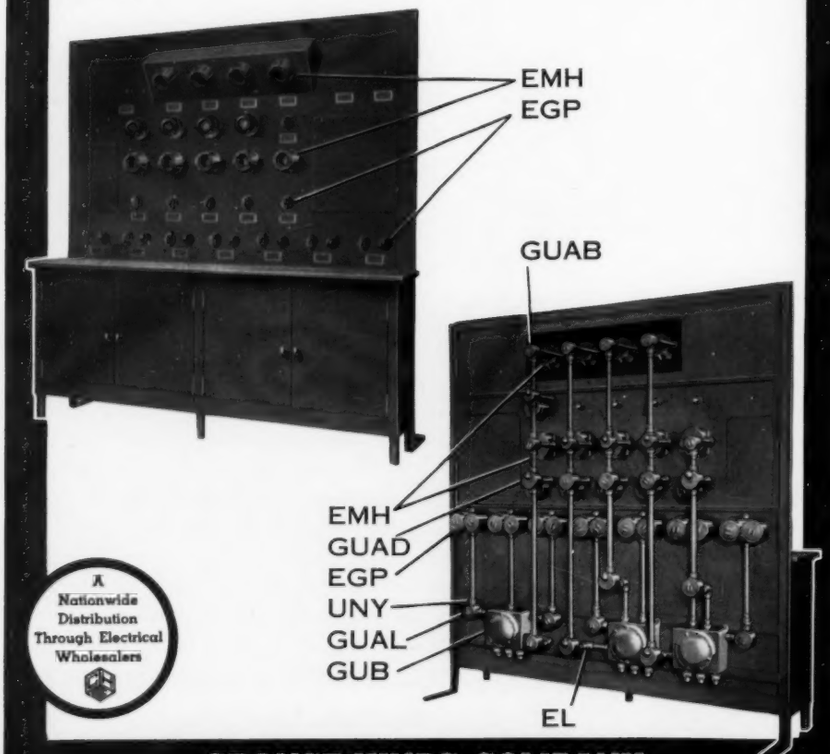
▲ Two open hearth furnaces of the American Steel and Wire Company, a subsidiary of United States Steel Corporation which have not been in operation for several years, are being rebuilt at Duluth, Minnesota. These two furnaces when placed in operation will increase the annual ingot capacity of American Steel and Wire Company to the extent of 174,000 tons.

The company at present has five furnaces in operation in Duluth and will have seven when the two now being rebuilt are completed. The first furnace is expected to be finished by the latter part of June and the other late in July.

CROUSE-HINDS

Engineering and Manufacturing Service

For over forty years the Crouse-Hinds Company has been the leader in the design and manufacture of electrical conduit fittings (Condulets) for usual and unusual conditions. The illustrations below show a complete explosion-proof control board in which standard Condulets have been used. This is one of the many special jobs engineered and built by the Crouse-Hinds Company.



A Nationwide Distribution Through Electrical Wholesalers

CROUSE-HINDS COMPANY
SYRACUSE, N. Y., U. S. A.

Sales Offices: Birmingham — Boston — Chicago — Cincinnati — Cleveland — Dallas — Detroit — Houston — Kansas City — Los Angeles — Milwaukee — Minneapolis — New York — Philadelphia — Pittsburgh — San Francisco — Seattle — St. Louis — Washington

Resident Salesmen: Albany — Atlanta — Baltimore — Buffalo — Charlotte — Denver — Louisville — New Orleans

CROUSE-HINDS COMPANY OF CANADA, LTD., *Main Office and Plant:* TORONTO, ONT.

WITH HIGH EFFICIENCY . . . PROVED RELIABILITY

USE WESTINGHOUSE IGNITRON RECTIFIERS . . . 650,000 KW. NOW INSTALLED OR ON ORDER

Industry is turning more and more to Westinghouse Ignitron Rectifiers as the answer to power conversion problems. Where Ignitrons are installed, efficiency goes up—power costs come down. The Westinghouse single tube design of Ignitron Rectifier provides a short arc path with high efficiency, without sacrifice of reliability.

That's why more than 650,000 kw of this Westinghouse equipment is now installed or on order.

It will pay you to call our local office and get complete information on how you can get economical power conversion with Ignitron Rectifiers.

WESTINGHOUSE ELECTRIC & MFG. CO.
EAST PITTSBURGH, PA.

A Westinghouse Ignitron Rectifier installed in a leading steel mill. Like other industries, the steel industry is finding the Ignitron Rectifier the solution to economical and dependable power conversion.

J-94463

Note small compact design of these Westinghouse Ignitron Rectifiers on final assembly line. Their light weight eliminates the need of special foundation. Absence of moving parts reduces maintenance costs.

A recent Westinghouse Ignitron installation in one of the nation's leading defense industries. With the elimination of special foundations and the ease of installation, Ignitron Rectifiers save installation time and cost.

IGNITRON RECTIFIERS

ITEMS OF INTEREST

Peter V. Martin has been advanced to the position of superintendent of the Gary Steel Works blast furnaces of the Carnegie-Illinois Steel Corporation.

Mr. Martin has been associated with the United States Steel Corporation subsidiary for the last 26 years, beginning as a messenger in the Cincinnati office of the company. Later he worked as a sampler in Pittsburgh and then was transferred to the South Chicago Works, where he worked his way through the ranks to the position of assistant superintendent of blast furnaces. He was transferred to the Gary Steel Works two years ago as assistant divisional superintendent of coke plant, blast furnaces and docks. He served in this capacity until receiving his new position.

He was born in Lima, Ohio. He was graduated from the Massachusetts Institute of Technology with a degree in metallurgy and subsequently took post-graduate work in physical chemistry, metallurgy and engineering science at Northwestern University and the Armour Institute of Technology.

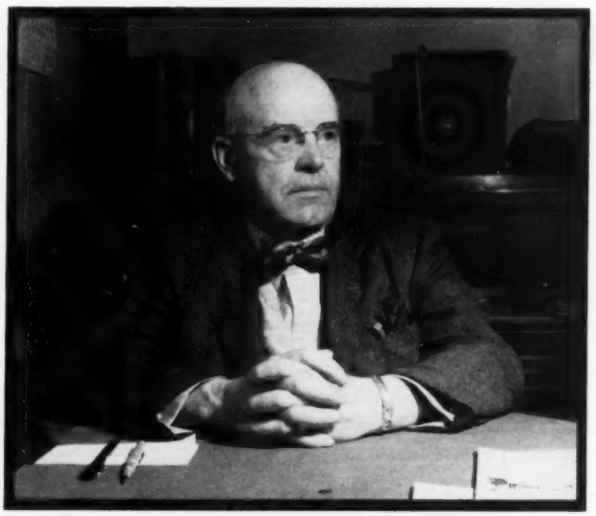
Mr. Martin is an active member of the Association of Iron and Steel Engineers, also of the Pig Iron and Ferro Alloys Committee of the American Iron and Steel Institute, and belongs to the American Foundrymen's Association, the Blast Furnace and Coke Association, Chicago District, and the American Institute of Mining and Metallurgical Engineers.

Clarence R. Burrell has joined the Tool Steel Gear and Pinion Company, Cincinnati, Ohio, in a sales capacity as assistant to E. S. Sawtelle, vice president and general manager.

Mr. Burrell was graduated from the University of Illinois in 1927 and was first employed by the Inland Steel Company as an industrial engineer. He became associated with the Farval Corporation and Cleveland Worm and Gear Company in 1929 and was assistant general sales manager of both companies prior to accepting his present position.

CLARENCE R. BURRELL, (left) *and* E. S. SAWTELLE

George H. Criss has been appointed Pittsburgh representative for the Baker Industrial Truck Company, Economy Engineering Company, Krane Kar of Silent Hoist Winch and Crane Company, International Conveyor and Washer Corporation, and Detroit Hoist and Machine Company. Mr. Criss is a graduate of the Western University of Pennsylvania, class of 1905. That same year, he opened an office in Cleveland, Ohio, for the Nernst Lamp Company, handling Nernst lamps, Cooper-Hewitt lamps and Cooper-Hewitt battery charging rectifiers. In 1906, he was loaned by the Nernst Lamp Company to the Kerling Brothers Interest of Toledo to overhaul their water works and electric light plant at Mount Pelier, Indiana. Upon completion of this job, Mr. Criss went to Tiffin, Ohio, another property of Kerling Brothers, Tiffin Gas and Electric Company,



GEORGE H. CRISS

and revamped this plant. He went back to the Nernst Lamp Company, Cleveland, Ohio, in January, 1907, and in August of that same year, went down to the southwest territory of the Nernst Lamp Company with headquarters at Fort Worth, Texas. Mr. Criss went back to Pittsburgh for the same company the following year as superintendent of maintenance and special work. In 1910, he transferred to Westinghouse Electric and Manufacturing Company, Pittsburgh office, and remained there until September, 1919. Leaving there, he spent one year with the Lakewood Engineering Company as head of the department for their Pittsburgh office on industrial trucks. He left them the first of October, 1920, and joined Mr. McCoy of the H. E. McCoy Company, handling Baker trucks. He remained with that company until Mr. McCoy's death in October,

PETER V. MARTIN

W. H. (BILL) BOYCE

THOMAS R. MILLER

1940. Mr. Criss has been a member of the Association of Iron and Steel Engineers for 28 years.

William H. Boyce has been appointed manager of industrial sales for the Delta-Star Electric Company, Chicago, Illinois. Prior to this new appointment Mr. Boyce had been assistant manager of the industrial division of this company since 1935.

Mr. Boyce had previously been associated with the Harris and Butler Company in Philadelphia and also had been electrical superintendent of the Tioga Steel Company of the same city.

Mr. Boyce has been a member of the Association of Iron and Steel Engineers since 1919.

Thomas R. Miller has been appointed Chicago District industrial engineer for the Carnegie-Illinois Steel Corporation, succeeding G. A. Whitehurst, who recently was transferred to Pittsburgh where he became assistant to chief engineer of the company.

Mr. Miller has been associated with the Gary steel works of Carnegie-Illinois for the last seven years. He began as a mechanical designer, then advanced to the position of plant industrial engineer, and also served as assistant division superintendent of the west mills, including the merchant mills. He leaves the position of superintendent of the maintenance division in the Gary plant to assume his duties in Chicago.

He began his industrial career in 1906 as an efficiency and operating engineer in New Castle, Pennsylvania. He later supervised rolling mills and power equipment of the Minnesota Steel Company in Duluth and in 1932 served as superintendent of power for the American Steel and Wire Company, United States Steel Corporation subsidiary, in Duluth.

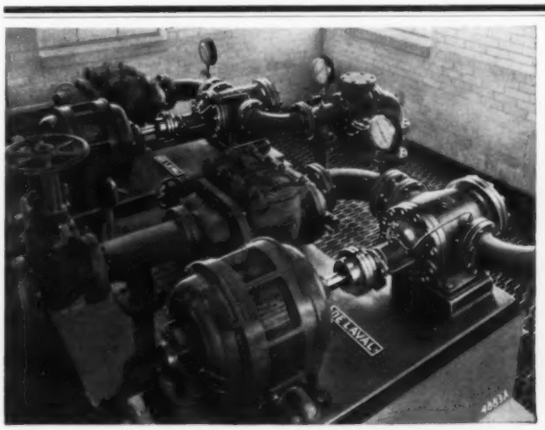
Mr. Miller is a native of Butler, Pennsylvania, and a graduate of the United States Naval Academy, where he received special training in steam and electrical engineering, as well as general engineering.

D. F. Farnsworth has been appointed superintendent of the No. 1–40 in. and 35 in. blooming mills and the 28–32 in. and 22 in. structural mills at South Works, Carnegie-Illinois Steel Corporation, Chicago, Illinois.

Mr. Farnsworth went to South Works in 1930 from the Worcester, Mass., plant of the American Steel & Wire Company, another United States Steel subsidiary, where he had been employed in the rolling mill and investigation department since 1925.

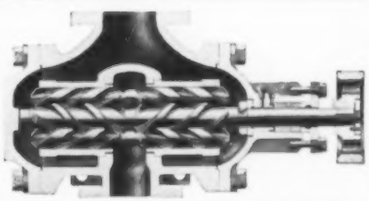
Beginning as an instrument man in the civil engineering department at South Works, he was soon trans-

(*Please turn to page 98*)



IMO

for fuel oil



These De Laval-IMO pumps transfer 100 g. p. m. each of Bunker C against 100 lbs. pressure. Other IMO's in the same plant deliver the oil to the burners at 300 lbs. All are coupled directly to the driving motors. There are no gears, and no valves, and the delivery is uniform, as from a continuously moving piston. Ask for Catalog 1-62.

IMO MOVE OIL

DE LAVAL STEAM TURBINE CO., TRENTON, N. J.

On their Way to Save Money on jobs like *these!*

Externally, these Enclosed, Fan-cooled A-C. Motors may lose some of their shine after landing on a steel-mill job, but internally, they will stay clean and dry.

• • •

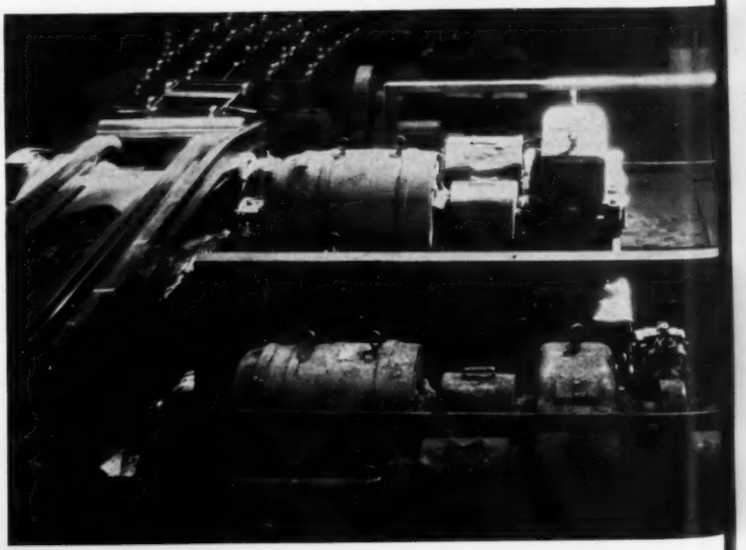
Steel mills are saving money with enclosed, fan-cooled Reliance Motors beeause they strike at the root of most motor troubles by keeping iron dust, scale, moisture, and oil away from windings and out of air gaps. They require less attention and help keep production moving at a steady pace The extra first cost is cheap insurance against lost tonnage.

• • •

In every country boasting a modern sheet mill you will find Enclosed, Fan-cooled Reliance Motors on automatic feeder-table drives like this. Not a clean spot, and it's hot (asbestos-covered or glass-covered wire is used for the stator windings).

Bulletins Nos. 120, 121 show how these motors are built to keep windings clean and dry.

Flying scale and water splashing from the mill sprays make things a bit mussy between the stands of a hot strip mill. But it's a good place to find out whether Reliance Fan-cooled Motors are as good as we say.



RELIANCE ELECTRIC & ENGINEERING CO.

1081 Ivanhoe Road Cleveland, Ohio

RELIANCE A-C D-C MOTORS

Birmingham, Boston, Buffalo, Chicago, Cincinnati, Detroit, Greenville (S. C.), Houston (Tex.), Los Angeles, New York, Philadelphia, Pittsburgh, Portland (Ore.), St. Louis, San Francisco, Syracuse (N. Y.), and other principal cities.

MECHANIZE *This man-killing Job*

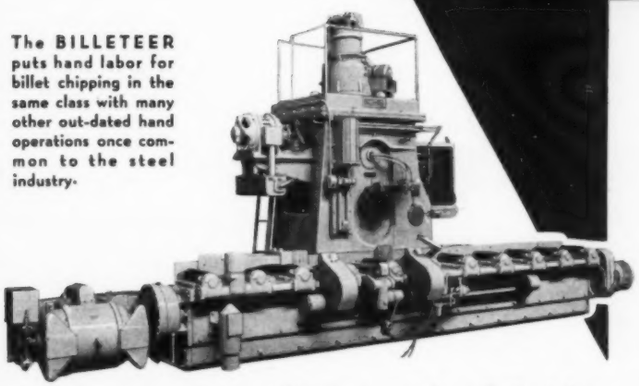
The BILLETEER

SAVES .. men for more important work

SAVES .... billets--not practical to clean by hand chipping

SAVES ..... UP TO 1/2 THE COST OF HAND CHIPPING

The BILLETEER puts hand labor for billet chipping in the same class with many other out-dated hand operations once common to the steel industry.



Write at once for all the information--Start saving and increasing production as soon as possible.

Today's emphasis on practical use of man power for maximum production at lowered cost is bringing into prominence the facts about BILLETEER'S economy and efficiency as established during ten years of operation in leading steel plants; many have bought their third and fourth BILLETEER on the strength of early experience with the savings produced by these machines.

BUILDERS OF BONNOT-LENTZ BILLETEERS ALSO CRUSHING PULVERIZING AND MIXING EQUIPMENT

THE **Bonnot** COMPANY

STEEL EQUIPMENT DIVISION

CANTON, OHIO

Items of INTEREST

(*Continued from page 95*)

ferred to the 28–32 in. structural mills as a mill investigator and subsequently served as warehouse foreman and special steel investigator of these mills. In 1936 he was made field engineer and a short time later became assistant superintendent of the 12–16 in. alloy mills, a position he held for three years. He has been assistant superintendent of the structural and blooming mills since 1939.

G. S. Mican has been appointed assistant division superintendent of rolling of the South Works, Carnegie-Illinois Steel Corporation, Chicago, Illinois.

Mr. Mican has been employed at South Works since 1919 when he began as an apprentice in the machine shop. He subsequently served in a number of capacities and in 1933 was made assistant superintendent of the 96 in. plate mill, four years later becoming superintendent of this mill. He has been superintendent of structural and blooming mills since 1940.

Mr. Mican is an active member of the Association of Iron and Steel Engineers.

Arno L. Billeter has been appointed as assistant to general superintendent in charge of manufacturing practice at the Irvin Works of the Carnegie-Illinois Steel Corporation.

Mr. Billeter has been employed by subsidiaries of the United States Steel Corporation since 1919. He worked at the Gary Sheet and Tin Mills until 1937, when he went to the new Irvin Works as superintendent of cold reduction. He has been superintendent of flat products finishing since October, 1938.

Thomas W. Hunter has been appointed superintendent of flat products finishing division at the Irvin Works of the Carnegie-Illinois Steel Corporation.

Mr. Hunter, a graduate in mechanical engineering from the Carnegie Institute of Technology, joined Carnegie-Illinois as assistant tin house superintendent at Shenango Works, New Castle, in December, 1936. He went to Irvin Works as assistant to the superintendent of tin finishing in September, 1937, and later became general foreman of cold reduction. He has been assistant division superintendent of flat products finishing since April 16, 1940.

Obituary

Harvey C. Castle, assistant superintendent of the cold roll strip mill of Jones & Laughlin Steel Corporation's plant, died Saturday, June 7, in Pittsburgh, Pa.

Mr. Castle was a graduate of Case School of Applied Science, Cleveland, and came to the Jones & Laughlin Corporation in 1938 from the Great Lakes Steel Corporation, Detroit, Michigan. He had been with the latter company from 1936 and prior to that had been with the Otis Steel Company of Cleveland since 1927. Mr. Castle had been an active member of the Association of Iron and Steel Engineers.

TRADE AUTOMATIC MARK

MANUFACTURERS FOR OVER THIRTY YEARS

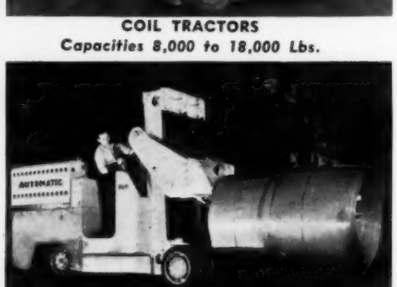
MODERN *Electric Propelled* INDUSTRIAL TRUCKS

FOR ECONOMICAL MATERIALS HANDLING

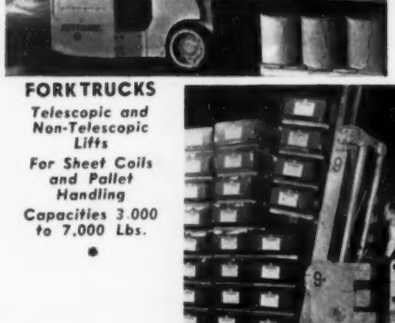
- COIL AND FORK TRACTORS
- SHEET AND TIN PLATE HANDLERS
- BOSH TRUCKS
- LOW AND HIGH LIFT TRUCKS
- LOAD CARRIERS
- TRACTORS — CRANES

COIL TRACTORS
Capacities 8,000 to 18,000 Lbs.

BOSH TRUCKS—*Tiering Type*



HEAVY DUTY COIL TRACTORS
Capacities Up to 30,000 Lbs.



FORK TRUCKS
Telescopic and Non-Telescopic Lifts
For Sheet Coils and Pallet Handling
Capacities 3,000 to 7,000 Lbs.

REQUEST DETAILS AND LITERATURE

SHEET AND TIN PLATE HANDLERS
Capacities 8,000 to 18,000 Lbs.—Non-Telescopic and Telescopic Lifts

Listed Under Reexamination Service of UNDERWRITERS' LABORATORIES

AUTOMATIC TRANSPORTATION CO.
47 W. 87th St. Div. of the Yale & Towne Mfg. Co. CHICAGO, ILL.